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A BIOLOGIC AND TAXONOMIC STUDY OF THE GENUS GYMNOSPORANGIUM

By FRANK DUNN KERN

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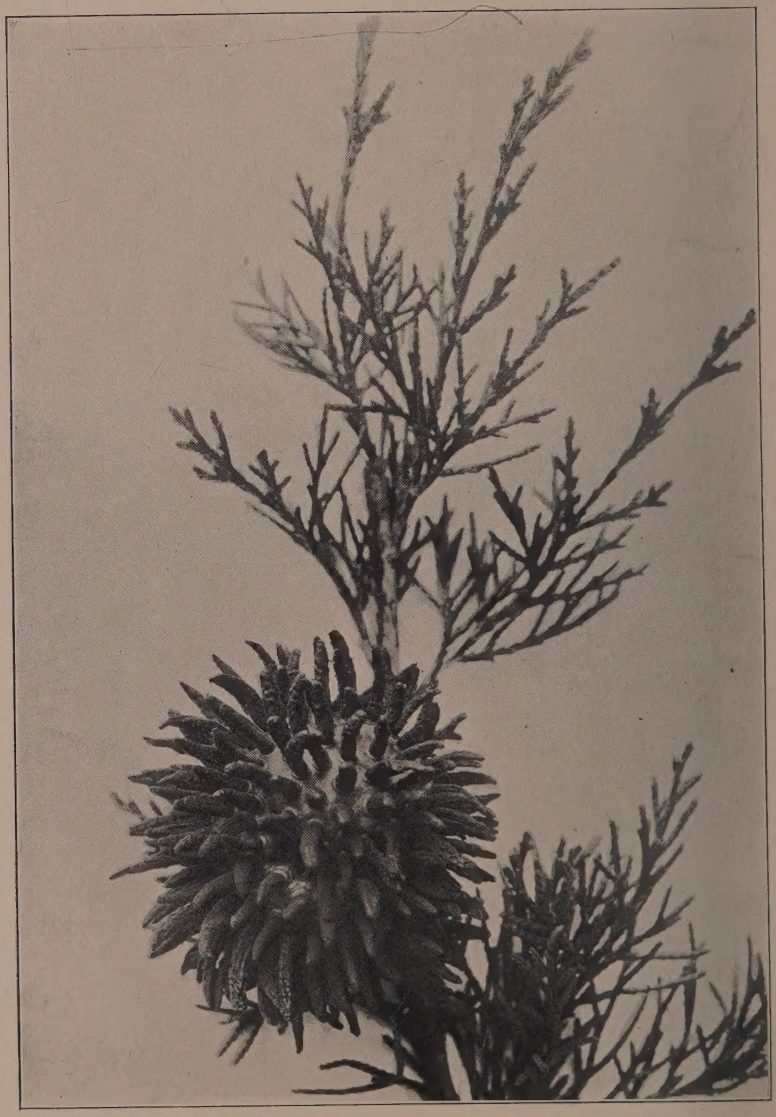

GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE

The Common "Cedar-apple"

A BIOLOGIC AND TAXONOMIC STUDY OF THE GENUS GYMNOSPORANGIUM

BY

FRANK DUNN KERN

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY, IN THE FACULTY OF PURE SCIENCE, COLUMBIA UNIVERSITY

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A Biologic and Taxonomic Study of the Genus Gymnosporangium

By Frank Dunn Kern

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PREFATORY NOTE

The investigations, the results of which are set forth in this paper, were begun in 1906 at Purdue University and have been continued at the New York Botanical Garden, and at Columbia University. To the officers and botanical staffs of these institutions the author would express his appreciation of the valuable aid rendered. The writer has also enjoyed the freest access to the private herbarium and library of Professor J. C. Arthur, of Purdue University, and is under obligation to him for many valuable suggestions and much kindly assistance.

In addition to the field studies made in the vicinities where the work has been carried on, several important collecting and observational expeditions have been made to the Rocky Mountains, one to the southeastern Atlantic states, one to the Mammoth Cave region of Kentucky, and numerous ones to various localities in Illinois, Wisconsin, and Michigan.

The experimental studies of life-histories have been carried on in the greenhouses of the Purdue University Agricultural Experiment Station, during the growing seasons from 1906–1910 inclusive. These experiments form a part of an extended investigation of rusts conducted by the Station and the results have been published in the annual reports of Cultures of Uredineae (Arthur, 1907, '08[1], '09, '10[1]), but are briefly reviewed here in order to bring together the scattered information relating to *Gymnosporangium*.

In addition to the herbaria of the institutions mentioned above, the writer has had access to the material in the Cryptogamic Herbarium of Harvard University, Mycological Collection of the U. S. Department of Agriculture, and the Arnold Arboretum. The following institutions have loaned for examination either a part or all of their specimens of the genus *Gymnosporangium:* Iowa State College, Cornell University, Connecticut Agricultural Experiment Station, Alabama Polytechnic Institute, West Virginia Experiment Station, Delaware College and Experiment

Station, Missouri Botanical Garden, and the University of Vermont. To the curators of these herbaria thanks are due and are hereby most heartily accorded for the privilege of examining the collections under their charge.

For collections of materials representing different localities and for various assistance, acknowledgments are due to Mr. E. Bartholomew, Stockton, Kans.; Rev. J. M. Bates, Red Cloud, Neb.; Professor E. Bethel, Denver, Colo.; Dr. J. J. Davis, Racine, Wis.; Professor W. G. Farlow, Cambridge, Mass.; Dr. Ed. Fischer, Bern, Switzerland; Professor F. D. Heald, Austin, Texas; Dr. G. G. Hedgcock, Dr. Perley Spaulding, and Mr. Carl Hartley, Washington, D. C.; Professor E. W. D. Holway, Minneapolis, Minn.; Professor H. S. Jackson, Corvallis, Oregon; Professors M. E. Jones and A. O. Garrett, Salt Lake City, Utah; Professor F. E. Lloyd, Auburn, Ala.; Dr. Donald Reddick, Ithaca, N. Y.; Mr. A. B. Seymour, Cambridge, Mass.; Dr. A. R. Sweetser, Eugene, Oregon; Dr. H. Sydow, Berlin, Germany; Dr. W. Tranzschel, St. Petersburg, Russia; Dr. Roland Thaxter, Cambridge, Mass.; Professor S. M. Tracy, Biloxi, Miss.; and to generous friends in various parts of the country who have severally contributed specimens. I am also indebted to Mr. W. W. Eggleston of the U. S. Department of Agriculture, and to Mr. J. G. Jack of the Arnold Arboretum, for the determination of certain host plants.

The writer was first induced to begin a study of this group chiefly because of the great need of systematic work which is at once apparent to any one who attempts to determine specimens either of the cedar or apple rusts. Much work has been done with the group, and this fact, doubtless, has led many to suppose that it was well worked and that most of the problems concerning it were settled. In taking up the study of the group, the writer, however, experienced much difficulty both because the data left by the past workers were chaotic and especially because they were incomplete. An incentive for the continuation of these studies has been the possibility that a detailed study of such a parasitic group, with its restricted hosts and abbreviated life-cycles, might throw light on some of the broader biologic problems such as the nature of relationships between hosts and parasites, and the possible origin and present trend of development among pleomorphic and heteroecious forms.

The geographic range which these studies have covered has

been gradually extended until it is now possible to present a treatment of all the species that have been described from any part of the world up to the present time, so far as they are known to the writer.

PART I

BIOLOGY OF THE GENUS GYMNOSPORANGIUM

1. Introduction

Life-History

The genus *Gymnosporangium* is composed of a group of species of strictly parasitic fungi having pleomorphic spore-forms. It is a member of the order Uredinales Diet. and is one of the several genera in that order in which an alternation of phases and heteroecism is conspicuously shown. The mycelium of one phase produces two spore-forms, pycnia (spermogonia) and aecia (aecidia), and inhabits, with three known exceptions, dicotyledonous angiosperms of the order Rosales, family Malaceae (Pomaceae). The mycelium of the other phase produces only one spore-form, telia (teleutosori) and inhabits, without any known exceptions, gymnosperms of the order Pinales, family Juniperaceae (Cupressineae). *Gymnosporangium* differs from all the other rust-genera which are heteroecious, except *Calyptospora*, by the lack of a repeating spore-form,* uredinial-stage (uredo-stage), in its life-cycle. It is a general rule that all species of the order Uredinales which are heteroecious possess four spore-forms, pycnia and aecia on one set of hosts and uredinia and telia on the other set, and it is a notable fact that only in the genera *Gymnosporangium* and *Calyptospora* are found species which are heteroecious and yet have one of these spore-forms omitted. In these two genera urediniospores are lacking in all of the present known species.

General Characters

Gymnosporangium as a genus is characterized, with a few exceptions, by a dingy-white, membranous peridium (called also pseudoperidium), which elongates into a tubular form and tends to rupture along the sides; by large, loosely joined, peridial cells usually conspicuously sculptured on the inner and side walls; by aeciospores having colored, mostly brownish, walls, usually with evident germ-pores; and by teliospores having hyaline pedicels,

* A *repeating spore-form* is one which may reproduce the same stage over and over indefinitely.

usually of great length, the outer portions of which swell in moisture and become gelatinized to form a jelly-like matrix in which the spores appear imbedded. Of further interest in connection with the telial stage are the characteristic swellings and galls which are produced by many of the species.

Comparison with Other Rust-Genera

Several other uredineal genera, *Coleosporium*, *Melampsoropsis*, *Pucciniastrum*, *Melampsorella*, *Melampsoridium*, and *Cronartium*, are known to have their antithetic phases inhabiting dicotyledonous angiosperms and coniferous gymnosperms and in all these

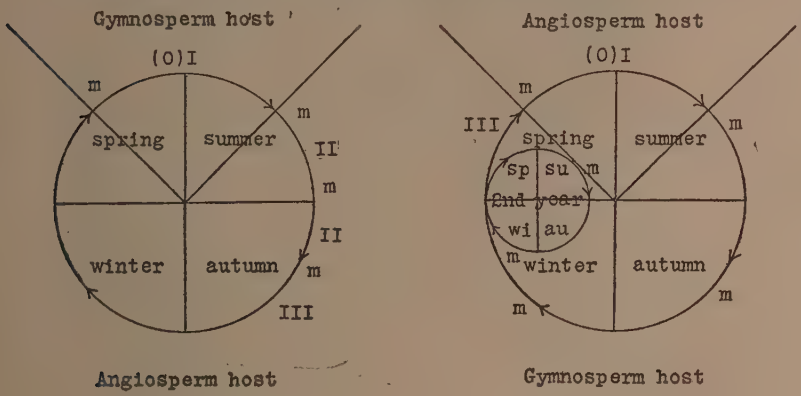


Fig. 1.—Diagrams to illustrate the life-history of rusts: **a**, the genera Coleosporium, Melampsoropsis, etc.; **b**, the genus Gymnosporangium. The symbols *O*, I, II, III, denote pycnia, aecia, uredinia, and telia respectively; *m*, mycelium. The repetition of any of the symbols indicates the repetition of that stage. The smaller circle in **b** is to indicate that the mycelium may continue on the gymnosperm host a second year before producing teliospores.

the angiosperms bear the telia and the gymnosperms the aecia, but the order in *Gymnosporangium* is just the reverse. It is the only genus having this reverse order and as might be expected the reversal in the sequence of hosts is accompanied by a new departure in the physiological functions of the spores. In the genera mentioned above, *Coleosporium*, *Melampsoropsis*, etc., the teliospores,

on the angiosperms function as resting spores, serving to carry the fungus through the winter, germinate in the spring and produce the aecial phase on the gymnosperms, where it remains until summer when it passes back to the angiosperm host again. In *Gymnosporangium* the teliospores are on the gymnosperms. They are active spores germinating upon maturity, producing the alternate phase on the angiosperm host, where it remains about the same length of time that the aecial phase of the other genera remained on the gymnosperm host, *i. e.*, about one quarter of the year, passing back in the late summer to the gymnosperm host. Here mycelium is produced which functions as a resting stage during the winter or possibly during two winters in some species. The foregoing diagrams may serve to illustrate these points.

Nuclear History

Although the nuclear phenomena in the rusts have been receiving considerable attention from cytologists in recent years, not a great deal of work has been done with the members of this group. Sappin-Trouffy (1896) and Blackman (1904) have used some of the species, especially *G. clavariaeforme*, in tracing certain of the nuclear changes. While our knowledge is still incomplete, it may, nevertheless, be well to briefly call attention to a few of the more essential points which have been demonstrated.

The basidiospores (sporidia) are uninucleated and give rise to a uninucleated mycelium which bears pycniospores, also uninucleated. At the base of the aecia, which soon begin to be formed from the same uninucleated mycelium which produced the pycnia, conjugation or cell-fusion takes place. This results in a binucleate condition of the aeciospores, owing to the fact that the nuclei from the two conjugating cells do not fuse. These nuclei divide conjugately in the mycelium originating from the aeciospores and remain separate until the teliospores are produced, where fusion is usually effected by the time the teliospores are mature.

It is to be noted that the method of conjugation in the type of aecium possessed by the species of *Gymnosporangium* has not yet been made clear. The work of Richards (1896), Olive (1908), and others indicates that in an aecium of this type the "fusion cell" does not at once function as a basal cell at the bottom of each spore-column, as it does in some types of aecia, but that large multinucleated cells first develop after conjugation and that the

spore-columns originate as branches from these large multinucleated cells.

It has been suggested by a number of investigators that this nuclear history represents an alternation of generations. According to this view the gametophytic generation is uninucleated, has the reduced number of chromosomes, and beginning with the basidiospores gives rise to the pycnia with their pycniospores. The sporophyte is binucleated, has the double number of chromosomes, and beginning with the aeciospores gives rise to the telia with their teliospores (also to uredinia with their urediniospores when they appear). The gametophytic number of chromosomes is restored by a reduction division when the teliospore forms the four basidia in germination.

2. Distribution and Relationships

Problems

It is at once evident that the same environmental factors which affect the distribution of the higher plants cannot have the same influence, at least they cannot operate in the same way, on the distribution of parasitic plants. It is also so apparent, as to scarcely require mention, that the geographic distribution of the obligate parasite is limited by the distribution of hosts and cannot be found outside of their range. But as to whether the distribution of the parasite is coextensive with the range of the hosts, as it might be provided there were no other operating factors than the mere presence or absence of the hosts, is quite another question. In order to throw some light on this problem and to discover, if possible, the existence and nature of other factors, the distribution of the species of *Gymnosporangium* has been worked over. In this genus, where all but one of the known species are heteroecious, there is a possibility of gaining some idea (1) of the dependence of the fungus upon its two sets of hosts, (2) of the relation of the distribution of these sets of hosts to each other, and (3) of the comparison between that relationship and the distribution of the fungus. This opportunity is one peculiar to this genus because of its lack of repeating spores, *i. e.*, spores which are able to grow again on the same host and reproduce the phase from which they were derived, and of the consequent absolute necessity for the association of the two sets of hosts as a condition in the distribution of the fungus.

General Discussion of the Data of Distribution

In order to make some of the facts to be discussed more available for reference than they are in the systematic monograph of Part II some of the data of distribution have been arranged in tabular form (tables I, II and III).

TABLE I.—Distribution of the Species of Gymnosporangium according to the Telial Hosts and the Continents

Telial Hosts			Total No. of Species	North America	Europe	Asia	Africa (Algiers)
Order	Family	Genus					
Pinales (Coniferales)	Juniperaceae	Juniperus § Sabina	21	18	3	1 (Central)	–
		Juniperus § Oxycedrus	7	5	5	–	1
		Chamaecyparis	4	3	–	1 (Japan)	–
		Heyderia	1	1	–	–	–
		Cupressus	1	–	–	1 (India)	–

Upon examination of table I, attention is perhaps first drawn to the fact that the genus *Gymnosporangium* is known only in North America, Europe, Asia, and northern Africa. This is a case of host-limited distribution, the members of the family Juniperaceae being found only in the temperate zone of the northern hemisphere, extending in some places to the verge of the tropics. Also, most of the members of the family Malaceae, at least those that serve as hosts for *Gymnosporangium*, inhabit only the northern hemisphere.

Certain additional facts must be presented in connection with table I in order to bring out the essential features of the distribution of the species inhabiting the genus *Juniperus*. There is only 1 species which is known to inhabit both sections of the genus, that being *G. germinale*, a North American species. Of the 20 species inhabiting only § *Sabina*, 17 occur exclusively in North America, the remaining 3 in Europe, while 1 of the European species is also in central Asia. With the species inhabiting § *Oxycedrus*, the situation is quite different. Of the 6 species occurring exclusively on this section, 1 is distributed in North America, Europe, and northern Africa, 2 more are common to both North America and Europe, 2 are known only in Europe, and 1 only in North America.

It is worthy of note that the species inhabiting § *Sabina* are divided between the eastern and western continents, while of those inhabiting § *Oxycedrus*, at least 3 are distributed in both eastern and western hemispheres. In seeking to discover what might account for such a distribution one can scarcely avoid the suggestion that the phylogeny and distribution of the hosts may have been an important factor. It seems to be generally accepted that § *Oxycedrus*, with its subulate leaves, is of earlier origin than § *Sabina*, with its leaves awl-shaped when young and scale-like when mature. The same species of § *Oxycedrus*, *J. communis* and *J. sibirica*, are widely distributed over the cooler temperate regions of all the continents of the northern hemisphere. Such a wide distribution must have occurred during a geological period when the land conditions permitted migrations between the northern continents. If the species of *Gymnosporangium* were parasitic on these forms at this early time we would expect them to be widely distributed along with their hosts. Although no fossil species of *Gymnosporangium* are known, the existence of other fossil fungi makes the assumption of the existence of *Gymnosporangium* at this age not improbable. If § *Sabina* has developed from § *Oxydecedrus* and has done so since the continents have been isolated, we would not then expect to find the same species, either of hosts or fungi, indigenous in North America and in the Old World; and this, indeed, is the case so far as the writer has been able to learn.

As to why there should appear to be so many more species occurring on § *Sabina* in North America (18) than in Europe (3) a few suggestions may be offered. In the first place it may be said that the field and culture work of the writer has all been done in North America and that owing to this work the number of species known here has been somewhat extended in recent years, while similar studies have not been carried on to the same extent in Europe. The ratio 18:3 may therefore not represent the actual conditions but is to be taken to represent the conditions as they are now known to the present writer. In the second place, even with the fullest studies, the balance might be expected to be in favor of North America, partly because of the relatively greater development of the species of this section (*Sabina*) here than in Europe, but chiefly because of the larger number of species and far more complex development of the family Malaceae, the hosts of the alternate phases.

TABLE II.—Distribution of the Species of Gymnosporangium according to the Aecial Hosts and the Continents

Aecial Hosts			Total No. of Species	North America	Europe	Asia	Africa
Order	Family	Genus					
		Crataegus	11	10	2	–	–
		Amelanchier	12	11	1	–	–
		Pyrus	7	3	2	2	–
		Malus	6	4	1	1	–
Rosales	Malaceae (Pomaceae)	Sorbus	6	4	3	1	–
		Aronia	4	4	–	–	–
		Cydonia	5	4	2	–	–
		Cotoneaster	2	–	2	–	–
		Pourthiaea	2	–	–	2	–
		Peraphyllum	1	1	–	–	–
		Mespilus	1	–	1	–	–
Rosales	Rosaceae	Porteranthus	1	1	–	–	–
Rosales	Hydrangi-aceae	Philadelphus	1	1	–	–	–
		Fendlera	1	1	–	–	–
Pinales	Juniper-aceae	Juniperus § Sabina	1	1	–	–	–

The suggestion of aecial hosts may lead to a consideration of table II. *Crataegus* and *Amelanchier* are seen to serve as hosts for many more species in North America than in Europe. This, it would seem, must bear some relation to the greater complexity and the more general distribution of these genera in North America. With regard to *Pyrus* the situation is entirely different, there being a total of 7 species known on this host almost equally divided between North America, Europe, and Asia. Certain other apparent discrepancies are at once understood when the distribution of the hosts is considered. *Aronia* and *Peraphyllum* serving as hosts only in North America are exclusively American genera; *Cotoneaster* and *Mespilus*, two hosts which are not recorded for North America, are not American genera; and *Pourthiaea*, recorded only for Asia is a strictly Asiatic genus.

Relationships between the Antithetic Hosts of Heteroecious Species

By a comparative study of the various species of *Gymnosporangium* an attempt has been made to discover something which might give a clue to an explanation why the families Juniperaceae and Malaceae are so universally and almost exclusively utilized as hosts. Although the efforts have not been productive of any positive results, certain data seem worthy of presentation. It is a notable

fact that there are only two known species which inhabit hosts outside of the families mentioned above, those being *G. exterum*, whose aecial host is *Porteranthus stipulatus*, an herbaceous plant of the family Rosaceae, and *G. gracilens*, whose aecial hosts are *Philadelphus* and *Fendlera* of the family Hydrangiaceae.

One suggestion which naturally presented itself in this study concerns the relation of the distribution of the hosts of the different phases. In many of the heteroecious rusts there occurs in one phase a stage which is capable of reproducing itself upon the host which bore it, and in such species it is obvious that the distribution of the phase possessing this repeating stage is not very dependent on the other phase. Consequently one phase might, if its hosts permitted, spread far beyond the distribution of the hosts of the alternate phase. Examples of this situation are so common as to scarcely need mentioning. It is a well-known fact that the black rust of wheat and other cereals and grasses is widespread in areas where the barberry bush is unknown. Another conspicuous example is the leaf rust of rye which is common in North America but which has its alternate phase on a member of the Borage family which is practically unknown in North America, and the alternate stage has never been detected on this continent.

As has been previously stated, the genus *Gymnosporangium* possesses no such repeating stage in the present known species and the result is that the association of the hosts of the alternate phases is a necessary condition for the perpetuation and distribution of the fungus. It is well known that the mycelium of the telial stage of many species is perennial, and it has been claimed in certain instances that the mycelium of the aecial stage may be perennial (von Tubeuf 1907), but since the mycelium cannot spread from one individual host to another the distribution of the species is still dependent on the association of the alternate hosts. As to just how close this association must be, no very definite limit can be set. The spores, doubtless, under usual conditions can be blown for distances varying from a few feet up to several miles. Thaxter (1891) mentions a case where he is certain that infection resulted from spores blown about eight miles. It is not probable that either under the most favorable or unusual conditions that spores could be carried any very great distance and we are therefore in a favorable position to study the comparative distribution of the alternate hosts in this genus.

The studies have been confined to North America and necessarily of course to those species which are known in both phases, eighteen having been selected for this purpose. While not yielding any results from which impartant generalizations may be made, it may be worth while to present some of the facts as follows:

A. Geographic distribution of the two sets of hosts very similar or almost coinciding—
   (1) *G. Juniperi-virginianae*, (2) *G. globosum*.

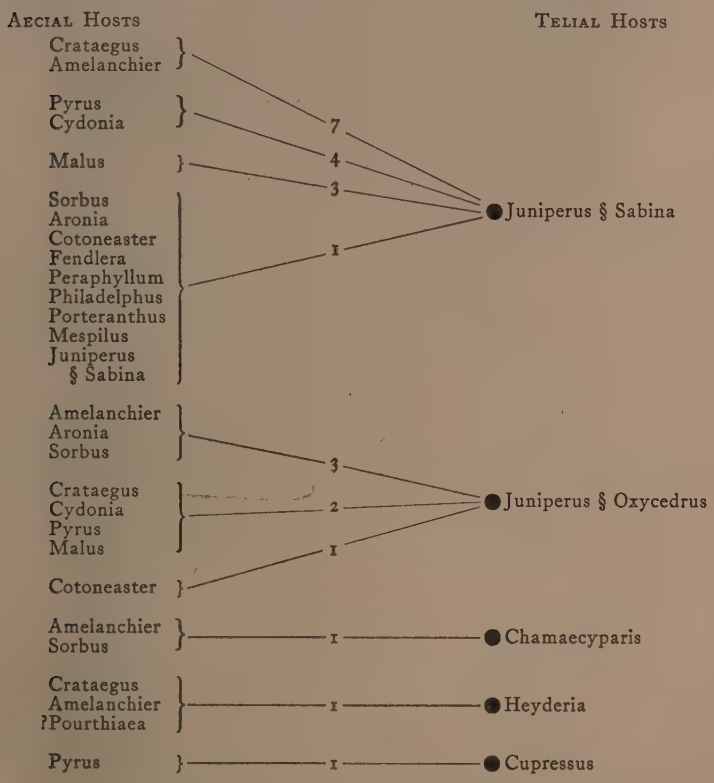
B. Geographic distribution of the two sets not coinciding, one much restricted and included within the other—
   a. Range of aecial hosts included within the range of the telial hosts—
      (1) *G. trachysorum*, (2) *G. exterum*, (3) *G. floriforme*, (4) *G. juniperinum*, (5) *G. germinale*, (6) *G. corniculans*, (7) *G. exiguum*.
   b. Range of telial hosts included within range of aecial hosts—
      (1) *G. Botryapites*.

C. Geographic distribution which is common to both sets only a portion of the distribution of either set—
   (1) *G. Nelsoni*, (2) *G. Davisii*, (3) *G. inconspicuum*, (4) *G. Blasdaleanum*, (5) *G. Betheli*, (6) *G. clavariaeforme*, (7) *G. Nidus-avis*, (8) *G. cornutum*.

While it is impossible to escape the conviction that some extraordinary relationship must exist between the sets of hosts occupied by a heteroecious form in its alternate phases the above facts scarcely indicate that the two sets would have been selected because of geographic distributions as now existing. If similar distributions or constant associations of the antithetic hosts are in any measure accountable for their utilization, and it is possible to conceive that they may have had considerable determining power, it is most likely that it was the distribution in very early times, when these fungi were in an unstable and perhaps weakly parasitic condition, that may have had an effect. It seems that very little is to be gained from a study of present day conditions which have become altered by so many factors. The fact that so many species have the range of the aecial hosts included within the range of the telial hosts is noteworthy and calls attention to the fact that in this regard there is a resemblance to the conditions prevailing in most heteroecious species which possess

repeating spores. It suggests that the species of *Gymnosporangium* are different from the other heteroecious rusts chiefly in the lack of repeating spores and that if in the past such a stage existed that this group would have conformed very well with other heteroecious groups.

TABLE III.—Showing the Number of Species Alternating between the Host Genera of the Two Antithetic Phases



In order to gain some idea of the different "affinities" existing between the host genera of the antithetic phases, a study of the number of species alternating between the various antithetic hosts has been made and the data are graphically presented in table III. It is not likely, though, that the number of species

alternating between two sets of hosts can be taken as a measure of the "affinity" or "relationship" existing between them, and yet the results of this compilation are not without interest and perhaps significance. In considering table III it must be borne in mind that oftentimes several genera serve as aecial hosts for a species, which with a single exception (*G. germinale*) is limited to one genus, or section, for its telial hosts. *Crataegus* and *Amelanchier*, serving as the hosts for 11 and 12 species, respectively, are very much in the lead of the other aecial hosts. As the conditions are now known from cultures, *Amelanchier* seems to be of a more generalized type, serving as host for species coming from 4 of the 5 sets of telial hosts while no other aecial host serves for more than 3 of the telial host-groups.

Factors Affecting the Distribution of Gymnosporangium

The data concerning the relation of the distribution of the fungi to the area over which they might be distributed, so far as host conditions are concerned, may be expressed thus:

A. Species of *Gymnosporangium* having known distribution within or practically coextensive with the area common to both sets of hosts—

a. Distribution practically coextensive with area common to both sets of hosts—

(1) *G. Juniperi-virginianae*, (2) *G. globosum*, (3) *G. Nidus-avis*, (4) *G. Nelsoni*, (5) *G. Davisii*, (6) *G. inconspicuum*, (7) *G. Blasdaleanum*, (8) *G. Botryapites*.

b. Distribution in central part of area common to both sets of hosts—

(1) *G. trachysorum*, (2) *G. exterum*, (3) *G. Betheli*, (4) *G. floriforme*.

(Mostly little known species—when thoroughly collected may possibly belong under *a*.)

B. Species having known distribution in no apparent relation to area common to both sets of hosts, sometimes in isolated districts—

(1) *G. clavariaeforme*, (2) *G. cornutum*, (3) *G. juniperinum*, (4) *G. germinale*, (5) *G. corniculans*, (6) *G. exiguum*.

From the foregoing data it becomes evident that the tendency is toward the distribution of the fungi over the entire geographic

area which provides the necessary host conditions. Even with the numerous cases which appear to be exceptions the argument in favor of this tendency is still strong when the full data concerning the apparent exceptions are considered.

In the first place, we are not yet in a position to say just what the geographic distribution of some of the species of fungi really is because of insufficient field work. The four species (under A, b) which are said to be distributed in the central part of the area common to both sets of hosts are comparatively little known species. When they are thoroughly collected they will doubtless be found to have a broader distribution than that known at present. The six species (under B) cited as bearing no apparent relation to the area over which they might be distributed also need further investigation before definite conclusions can be drawn. *G. clavariaeforme*, for example, is known from Maine and Delaware west to Wisconsin and northeastern Iowa and also in Colorado and Wyoming. The host conditions are furnished in the area between these regions through Minnesota, North Dakota and Montana but so far as the writer knows the fungus has not been reported from any of these states. The proper association of hosts for this species also prevails clear across southern Canada, but the fungus has apparently not been collected in this whole area. Whether the lack of collections from these regions can be taken to indicate that the fungus does not occur there seems very doubtful. It is much more probable that it indicates lack of well directed efforts toward collecting. *G. juniperinum* appears to furnish a much better example of a possible exception to the tendency of distribution over the common host area than do any of the other species listed above. The hosts of this species, *Sorbus*, and *Juniperus* § *Oxycedrus* are associated together from Labrador across southern Canada and the great lake region to the Rocky Mountains but the fungus is only known in the Rocky Mountain region from Alberta and British Columbia south to Colorado.

Taken as a whole the evidence regarding the distribution of the heteroecious species in this group indicates that the association of the two sets of hosts furnishes the necessary conditions for the growth of the fungi and that wherever this association prevails we may expect, either now or eventually, to find the fungi. There is practically nothing to indicate that other factors such as temper-

ature, amount of precipitation, or character of the soil have any direct influence on the distribution of the fungi. It is well known that junipers and cedars occur in diverse climates and on widely different soils, and on hosts in all these varying conditions the fungi thrive. Whether the host occurs in a warm region on a permeable sandy soil or in a colder place on wet marshy ground it is apparently equally susceptible to these fungi. The amount of rainfall and the temperature prevailing during the germinating time of the teliospores in the spring might have a seasonal or local influence on the prevalence of the fungi and in this indirect way these factors might have a slight but unimportant bearing on distribution.

Evolutionary Tendencies

Regarding pleomorphism and heteroecism there is no evidence brought forth by the investigation of this group which is of significance except as it is interpreted in the light of our present knowledge of other groups of Uredinales. There is, on the one hand, the view that the species with only two spore-forms (the so-called micro- and lepto-forms) are the most primitive (Dietel, 1899) and that the other species with more spore-forms (hemi-, brachy-, opsis-, and eu-forms) have been derived from them. Along with this view of pleomorphism, goes the generally conceived idea that autoecism is the primitive condition, heteroecism being considered a later adaptation (Klebahn, 1904). Opposed to these views, is the theory that pleomorphism and heteroecism are really the primitive condition of the order (Arthur, 1906, Blackman, 1904). This latter theory assumes that the production of the four spore-forms now known in the full life-cycle (eu-forms) was a very early condition in evolution and that the forms now extant with fewer spore-forms have been reduced by later influences. Similarly autoecism is derived from heteroecism by a reduction process.

It is not necessary to review here all the observations upon which these views are founded. Neither of the views explains the real origin of the group, but simply attempts to express the trend of evolution since a time when the group attained a more or less definite morphology and a parasitic mode of life. No assumptions need be made concerning what took place prior to this time in order to make out relationships between the various forms as they now exist. We are not so much concerned wth the question as to how these organisms acquired the parasitic

mode of life and developed into the form which we recognize as rusts, but rather as to whether the simpler types, as we know them, represent primitive or reduced forms.

The observations made in the course of the investigations of the genus *Gymnosporangium* appear to support the latter theory. *i. e.*, that the trend of development is toward reduction in the number of spore-forms and toward autoecism. The facts which have led to this interpretation may properly be considered at this time.

In most of the groups or tribes of Uredinales the four-spored* condition is common and in many the larger number of species belong to that class, but in *Gymnosporangium*, as has already been pointed out, a three-spored condition is wholly dominant, repeating spores (urediniospores) being lacking in present known species. It is evident, then, that the species of *Gymnosporangium* stand apart from four-spored forms either as more primitive or as somewhat reduced forms. Certain facts gained from morphology and others from life-histories have assisted in forming a judgment on this point. The roestelia-type of aecium, which prevails in the genus, certainly cannot be looked upon as primitive. With its elongated membranous peridium, made up of highly specialized peridial cells, and its colored aeciospores with their evident germpores, the roestelia-type of aecium is surely to be looked upon as a later development than the cupulate-type of aecium, such as prevails in the pucciniaceous forms. This being the case the presence of aecia of the ordinary cupulate-type in the genus *Gymnosporangium* may be regarded as a safe means of determining which are the more primitive species within the genus, and in this way we may throw some light on the more general problem.

G. Libocedri (see *G. Blasdaleanum* in part 2) a species of western America on *Heyderia decurrens* (better known as *Libocedrus decurrens*) has been shown by cultures to be related to *Aecidium Blasdaleanum*, an aecial form of the ordinary cupulate-type, on *Amelanchier* and *Crataegus*. This is the only experimental proof which we have of a relationship between a cupulate aecium and a species of *Gymnosporangium*, but by analogical reasoning it seems most certain that *Aecidium Sorbi*, another cupulate form, must

* In using this expression the writer refers to those forms sometimes called *eu*-forms. The four spore-forms are pycniospores, aeciospores, urediniospores, and teliospores.

also be related to a *Gymnosporangium* on some host belonging to the *Juniperaceae*. The writer has explained in some detail in another paper (Kern, 1910[1]) that there is within the range of *Aecidium Sorbi* no known *Gymnosporangium* to which it may belong, but that there is in very close association with it a cedar-rust in the form of *Uredo nootkatensis* on *Chamaecyparis nootkatensis* and that there is strong probability of a relationship between these two forms. This hypothesis is supported by inferences drawn from analogy, homology, and certain features in their geographic distribution. *Uredo nootkatensis* is an undoubted uredinial stage and from its host affinities its connection with a *Gymnosporangium*-like telial form is naturally to be anticipated.

In this way we come to the belief that a uredinial stage does occur within this group and that there is the strongest kind of evidence that it occurs in a species which has the cupulate-type of aecium, or, in other words, in a species which must be looked upon as primitive. There is also evidence indicative of the possession of other primitive characters. Since *G. Libocedri*, whose aecial stage is of the cupulate-type, has a small foliicolous telial stage, not causing any hypertrophy, we may by analogy predict a similar telial stage for the *Uredo nootkatensis-Aecidium Sorbi* combination. In considering the telial characters, it should be said, there is every reason to regard the small foliicolous forms which cause no hypertrophy as the most primitive, and the forms which occur on the branches with fusiform swellings and those which induce special gall-like outgrowths, as relatively more and more specialized.

This very probable appearance of a uredinial stage only in a species which possesses other characters in both the aecial and telial stages of an undoubted primitive nature, the writer interprets as a support for the view that the presence of the uredinial stage is in itself a primitive character. According to this theory, the possession of the cupulate-type of aecium, foliicolous telia, and presence of uredinia are characters of the most primitive species of *Gymnosporangium*. The suppression of the uredinial stage and the assumption of some of its functions by the aecial and telial stages appear to have been the first step in reduction, while the reduction in the hosts, or autoecism, has taken place much later. There is but one autoecious species known, *G. bermudianum*, and according to the foregoing view it would stand as the most highly

specialized representative of the group. The elongated, membranous type of peridium and the occurrence of both telia and aecia on galls fits in with this disposition.

The intimation that some of the functions of the uredinial stage have been taken over by the aecial and telial stages may be briefly explained. The chief function of the uredinia is to insure distribution by a rapid and extensive dissemination of the fungus. The long tubular peridium of the roestelia-type contains many more spores than the short cupulate-type and in this way larger dissemination is made possible. In many of the species of *Gymnosporangium* the telial stage has become perennial, and in this way continuity is insured, even though dissemination might be less rapid. The writer does not wish to convey the understanding that the assumption of the ordinary functions of the uredinial stage by the other stages is to be regarded as the influence which has suppressed the uredinia. The partial fulfillment of these functions by other stages may, on the other hand, be the result and not the cause of the disappearance of the uredinia. We are ignorant of the cause of suppression or reduction, but the disappearance of the uredinial stage and the development of new devices to perform its ordinary functions seem in some way to be correlated.

3. Experimental Investigation of Life-Histories

History

The species of *Gymnosporangium* were among the first heteroecious rusts in which a positive connection between the two alternating phases was experimentally proved by controlled inoculations. In the spring of 1865 Oersted (1865) showed by means of cultures carried out in the Botanical Garden in Copenhagen that the two fungi, *Gymnosporangium Sabinae*, inhabiting red cedar, and *Roestelia cancellata*, inhabiting the pear, were really but two phases in the life-history of a single organism. Oersted states that he had suspected this relationship in 1862 but was unable to actually carry out the experiment until 1865. It is interesting to note that he also suspected a similar connection between *Puccinia graminis* and *Aecidium Berberidis*, and in his communication describing his successful cultures with the cedar and pear rusts, June 10, 1865, he suggested that the same relation doubtless existed between the cereal and barberry rusts. On

June 15, 1865, after his paper had been sent to the printer he received word from DeBary concerning his successful culture with *Puccinia graminis* and *Aecidium Berberidis*. To Oersted, therefore, as well as DeBary we are indebted for much of the pioneer work with the heteroecious rusts. He was especially concerned with the species of *Gymnosporangium*, following up his earliest work with the demonstration of the life-history of "*Gymnosporangium juniperinum*" [*cornutum*] in 1866, and of *G. clavariaeforme* in 1867.

This early work showed such a new departure in development that contemporary botanists scarcely ventured to accept such a strange story and one can find skepticism even in the early writings of some who are still living. It is, therefore, not surprising that considerable time elapsed before additional work was done along this line. It was about fifteen years before further cultures were made with the cedar rusts by Hartig, in Germany, a little later by Farlow and Thaxter in this country, and by Plowright in England. Since that time this work has been further advanced by a number of investigators, among whom may be mentioned Barclay, Shirai, Fischer, Arthur, Yamada and Miyake, and others.

Necessity of Cultures

The fact having been once established that some of these fungi have their life-cycle divided into two distinct alternating phases, which inhabit wholly different and unlike host plants, the necessity of experimental cultures to supplement the former method of observation and description becomes at once apparent. The local association of any two such alternating phases in nature may lead one to suppose that the phases are related, but it requires actual cultures to show whether the supposition is correct or not. A culture in which a spore from one phase on one host is sown upon another host, and subsequently gives rise to a spore form of the alternating phase, is the only conclusive evidence that the two phases are related and represent different forms of the same organism.

Culture Methods

At this point it may not be out of place to describe briefly the methods which have been found most successful in cultivating the species of *Gymnosporangium*. In the first place it may be

said that better results have been attained by sowing the teliospores from the cedars upon the malaceous plants as trial hosts and making observations for the appearance of the aecial generation rather than the converse. The reason for this lies in the different nature of the telial and aecial phases. The teliospores are mature in spring and germinate at once. Following an inoculation from teliospores the first sign of infection, the pycnial stage, is to be expected in six to twelve days, while the second sign, the aecial stage, may be looked for in one to four months, the actual time varying with the different species. In this way the cultures are carried on during the normal growing season and results obtained before the close of the season. The converse cultures in which the aeciospores are sown upon the cedars require a much longer incubation period, at least through one winter season, and possibly through two in some species. This latter method being more tedious and less likely to result in infection is not so satisfactory for working out life-cycles, and yet it may have certain advantages that will be mentioned later.

It is possible to carry on cultures out-of-doors but owing to the many disturbing factors such as danger from outside infection, accidental destruction of the trial host and many others the writer has practically abandoned them in favor of indoor cultures. For indoor experiments small but vigorous growing potted plants are most desirable. Some of the earlier investigators used cut branches with the ends placed in water, and detached leaves in moist chambers, but it is impossible to keep these in fresh condition for a sufficiently long time. The use of rooted plants which must be kept growing vigorously in pots for several months makes it necessary to carry on the work in a greenhouse, the conditions being too unfavorable and artificial for vigorous growth except under glass.

In making the inoculations the writer now employs the method of suspending a portion of the branch or the gall bearing the telia over the trial host in such a manner that the basidiospores (sporidia) will fall naturally upon the desired area, either young leaves or shoots, or developing fruit, according to whether the form is supposed to be chiefly foliicolous, caulicolous, or fruiticolous. The whole is then sprayed thoroughly with a fine spray from an atomizer. Care is taken to thoroughly moisten the telia. Sometimes the twig or branch bearing them is immersed in water and allowed to remain a few moments, all excess water being taken off before

putting it in place. If the leaves of the trial host will not moisten they are rubbed between the fingers until the moisture will adhere. The plant is then covered with a bell-jar and set in a shaded place for a period of two or three days. The bell-jars are temporarily removed each day, aired and sprayed on the inside before being replaced. The bell-jar prevents rapid evaporation, thereby insuring the necessary moisture during the germination and infection period. During this period the plants are screened from the direct rays of the sun to prevent the temperature from rising too high. This scheme of first applying moisture to telia at the time when the sowing is to be made and of suspending the whole twig or gall directly over the parts to be infected has been found vastly better than that of removing the telia or spores, placing them in water and allowing them to germinate, and then attempting to apply the basidiospores with a brush or otherwise, as was first attempted by the writer following the lead of the earlier workers. One objection to the method as outlined above is that in the case of vigorous germination infection on a very susceptible host may be so great that the host may be severely injured by it and its further development checked. This may sometimes be overcome by washing off some of the basidiospores which can often be observed on the leaves of the trial host as a yellow powder. It is not necessary to make special tests for the germination of the spores, as is usually done with other genera of the rusts, for germination can nearly always be detected by the yellow and pulverulent condition of the surface of the spore-masses, if the aggregations of basidiospores cannot be seen by the naked eye on the trial host leaves as indicated above. In case of doubt a microscopic examination of some spores removed from a telium would soon settle the question. The species of *Gymnosporangium* are usually easy to bring to germination and yet some species have given considerable trouble and one species refused to germinate at all although the material was fresh and seemed in good condition.

Collection and Care of Culture Material

Telial material to be used for cultures is best when not collected until mature, and then used for sowing as soon afterward as possible. If fairly large specimens of the branches or twigs with some green leaves are secured, the telia will keep fresh for some time provided they are not allowed to become expanded with moisture.

Such specimens can be sent through the mail or express and be received in good condition, even after a long journey, if precaution is taken to wrap them in waxed paper such as florists use. I have received specimens from Europe in this way which were in a good viable condition. Specimens which have reached maturity in the field and have expanded after a rain and partially germinated are never so desirable as those which have never been expanded and gelatinized. Specimens which have been thoroughly dried for herbarium purposes are useless for culture work.

Author's Experimental Work

Five seasons[1] of culture work with the species of *Gymnosporangium* have been carried on as a part of the investigations summarized in this paper. Out of a total of 33 species now recognized in their telial phase, 26 have been available for the culture work. Successful cultures were secured in 18 of the 26 species tested. Of these, 9 were verifications of life-cycles previously ascertained and 9 gave aecial and telial connections never before recorded. In this work 233 individual plant cultures were attempted and 25 species of trial hosts were employed, belonging chiefly to the apple family, Malaceae (*i. e.*, Pomaceae). The following is a brief summary of the results of the work during the different seasons:

	1906	1907	1908	1909	1910	Total
Number of species of *Gymnosporangium* employed	3	10	16	12	11	26
Number of species successfully cultivated	3	8	11	11	5	18
Number of species cultivated for the first time	1	2	3	3	0	9
Number of plant cultures attempted	27	50	72	51	33	233
Number of species of trial hosts employed	10	13	16	17	13	25

Summary of Original Cultures

In order to bring together the scattered results pertaining to the cultures of *Gymnosporangium*, a table has been prepared giving a record of the first cultures of those species whose life-histories

[1]The sixth season has been progressing as this paper has been going through the press. Three new life-cycles have been worked out. See accompanying table of "Record of First Cultures" for details. The statistics as given above do not include the present season.

are known. A large amount of work for purposes of verification or extension of the range hosts has been done which it is impossible to mention here. In a few instances confirmatory cultures are mentioned when they have been the first ones made with American material or when the first cultures were inconclusive. The plan of this table is to indicate, first, the year when the work was performed, and secondly, the species of *Gymnosporangium* and its host, whenever that can be made out from the original report. Sometimes this information is not given directly, but if there is anything which leads to an inference I have included the possible host, using brackets to indicate that it is my insertion. Regarding the names, I have for the most part employed the name used by the original investigator, but for the sake of making it readily comparable I have in most instances inserted parenthetically the name applied to that form in this paper. Thirdly, the successful trial host, or hosts, and the aecial name of the resultant form, are given. This latter space is necessarily blank in many instances where the resultant aecial phase was never recognized and named as an independent form. The fourth column contains the name of the investigator and the reference to the original report. In some cases two names are given, separated by a semicolon, the idea being the same as where this method of citation is used in connection with the publication of a name, *i. e.*, that the first is largely responsible for the work and the second for the publication.

RECORD OF THE FIRST CULTURES PROVING RELATIONSHIPS BETWEEN THE SPECIES OF GYMNOSPORANGIUM AND THEIR ALTERNATE PHASES

Year	Species of Gymnosporangium Host of Culture Material	Trial Host Species of Roestelia	Investigator Place of Publication
1865	G. Sabinae [J. sabina]	Birnbaum [Pyrus] R. cancellata	Oersted, Bot. Zeit. **23**: 291. 1865.
1866	"G. juniperinum" [cornutum] Juniperus	Sorbus aucuparia R. cornuta	Oersted, Overs. Danske. Vid. Selsk. Forh. **1866**: 185–196. 1866.
1867	G. clavariaeforme [Host not given]	Weissdorn [Crataegus] Apfelbäumen [Malus] R. lacerata	Oersted, Bot. Zeit. **25**: 222. 1867.

1882 (or earlier)	"G. tremelloides" [juniperinum] [J. communis]	Sorbus aria Sorbus chamaemespilus Malus Malus R. penicillata	Hartig, Lehr. Baum-Kr. 133. 1882.
1883	"G. clavipes" [germinale] [J. virginiana]	Amelanchier Pyrus Malus Pyrus arbutifolia	Farlow (inconclusive), Proc. Am. Acad. **20**: 313–315. 1885.
1883	G. globosum [J. virginiana]	Crataegus Pyrus Malus	Farlow (inconclusive), Proc. Am. Acad. **20**: 312–314. 1885.
1885–1887	G. confusum [Mespili] J. sabina	Crataegus oxyacantha Aecidium Mespili	Plowright, Brit. Ured. & Ustil. 232. 1889.
1886	"G. biseptatum" [Botryapites] [Chamaecyparis thyoides]	Amelanchier canandensis R. Botryapites	Thaxter, Proc. Am. Acad. **22**: 263. 1887.
1886	G. clavariaeforme [Host not given]	Crataegus tomentosa	Thaxter (verification in America), Proc. Am. Acad. **22**: 262. 1887.
1886	"G. clavipes" [germinale [J. virginiana]	Amelanchier canadensis R. aurantiaca	Thaxter, Proc. Am. Acad. **22**: 264. 1887.
1886	G. globosum [J. virginiana]	Crataegus coccinea	Thaxter, Proc. Am. Acad. **22**: 263. 1887.
1886	G. Nidus-avis [J. virginiana]	Amelanchier canadensis	Thaxter, Proc. Am. Acad. **22**: 264. 1887.
1886	G. Juniperi-virginianae [J. virginiana]	Pyrus Malus R. pyrata	Thaxter, Proc. Am. Acad. **22**: 262. 1887.
1889	G. Cunninghamianum Cupressus torulosa	Pyrus Pashia	Barclay, Sci. Mem. Med. Off. India **5**: 76–78. 1890.
1897	G. japonicum J. chinensis	Pyrus sinensis R. koreaensis	Shirai, Zeits. Pflanzenkr. **10**: 1–5. 1900.
Prior to 1901	"G. flaviforme" [floriforme] J. virginiana	Crataegus spatulata	Thaxter; Earle, Contr. U. S. Herb. **6**: 186. 1901.
1906	"G. Nelsoni" [juvenescens] J. scopulorum	Amelanchier canadensis Sorbus americana	Arthur (Kern), Jour. Myc. **13**: 203. 1907.

1907	G. Betheli J. scopulorum	Crataegus coccinea Crataegus punctata R. Betheli	Kern; Arthur, Jour. Myc. **14** 23. 1908.
1907	G. Miyabei Chamaecyparis pisifera	Pyrus Miyabei Pyrus Aria R. solitaria	Yamada & Miyake, Bot. Mag. **22**: 21–28. 1908.
1907	G. inconspicuum J. utahensis	Amelanchier erecta R. Harknessianoides	Kern; Arthur, Jour. Myc. **14**: 24. 1908.
1907–1909	G. Amelanchieris Juniperus communis Juniperus nana	Amelanchier ovalis R. amelanchieris	Ed. Fischer, Zeits. f. Bot. **1**: 683–714. 1909.
1908	G. Davisii J. Sibirica	Aronia nigra	Kern; Arthur, Mycologia **1**: 241. 1909.
1908	G. exterum J. virginiana	Portherantus stipulatus	Kern; Arthur, Mycologia **1**: 253. 1909.
1908	G. cornutum Juniperus sibirica	Sorbus americana	Kern; Arthur (verification in America), Mycologia **1**: 240. 1909.
1908	"G. Libocedri" [Blasdaleanum] Libocedrus decurrens	Crataegus Pringlei Aecidium Blasdaleanum	Kern; Arthur, Mycologia **1**: 252. 1909.
1909	G. corniculans J. horizontalis	Amelanchier erecta Amelanchier canadensis	Kern; Arthur, Mycologia **2**: 235. 1910.
1909	G. exiguum J. virginiana	Crataegus	Kern; Arthur, Mycologia **2**: 234. 1910.
1909	G. trachysorum J. virginiana	Crataegus cerronis	Kern; Arthur, Mycologia **2**: 236. 1910.
1911	G. speciosum [gracilens] J. monosperma	Philadelphus coronarius	Cultures now in progress
1911	G. Nelsoni (=durum) J. scopulorum	Amelanchier	Cultures now in progress
1911	G. Kernianum	Amelanchier	Cultures now in progress
	G. bermudianum	No cultures—	Autoecious

Unattached Forms

In addition to the above species, whose life-histories have been experimentally demonstrated, there are a number of isolated forms,

which, from their morphologic characters, clearly belong in this group. Some of these are known only in the telial phase, others only in the aecial phase. The following is a list of these unattached forms recognized in this paper:

Aecial phase unknown	G. Ellisii	on Chamaecyparis	North America
	G. fraternum	" "	
	G. effusum	on Juniperus (§ Sabinae)	
	G. multiporum	" " "	
Telial phase unknown	G. Harknessianum	on Amelanchier	
	G. transformans	" Aronia	
	G. hyalinum	" Crataegus	
	G. tubulatum	" "	
	G. Sorbi	" Sorbus	
	G. Photiniae	" Pourthiaea	Japan
	G. Yamadae	" Malus	

Clues of Relationship

For most of the above forms there are no definite clues of probable relationships. Some of the telial and aecial phases may belong together, or, on the other hand, the alternate phases of the forms here listed may still be undetected. *G. Ellisii* has been thought by some to be connected with *G. transformans*, but this has never been demonstrated. The writer (Kern, 1910[1]) has suggested that *G. Ellisii* is more likely related to *G. hyalinum*. *G. Harknessianum* is a very striking form from California. It is similar in habit and external morphology to the aecia of *G. inconspicuum*, and by analogical inference I would suggest that it is probably related to an inconspicuous telial form occurring on the green branches, not causing hypertrophy, and having teliospores with carotiform pedicels. It is possible that *G. Sorbi* may turn out to have the most interesting life-cycle of all, if it should be related to *Uredo nootkatensis* on *Chamaecyparis nootkatensis*, as I have previously suggested (Kern, 1910[1]). For the two Japanese forms I am unable to make any suggestions.

In addition to the unattached aecial forms listed above, there is another form from Japan, *Aecidium Pourthiaeae* Sydow, on a malaceous host, *Pourthiaea villosa*, which doubtless has a cedar-rust for an alternate stage and belongs in this group. In structure and habit this form is so similar to the North American species, *G. Libocedri* (*Blasdaleanum*), which is connected with a telial form on *Heyderia decurrens* (generally referred to as *Libocedrus decurrens*) that it has been thought best to treat it as a doubtful

synonym of that species until cultures can definitely determine its relationship. The fact that there is in the Orient another species of the genus *Heyderia*, which might harbor the telial stage there, lends support to the above suggestion.

Development of the Telial Stage

The telial stage of a number of species, especially those producing fusiform swellings on the branches, has long been known to be perennial, but Plowright (1889) was the first to show by means of cultures the nature of the early development of such a form. He found in experimenting with *G. clavariaeforme* that the "aecidiospores require two years in which to perfect the development of perennial teleutospore mycelium." Aeciospores were sown upon a juniper on June 25, 1884; about two weeks later some of the leaves turned yellow and during the autumn these fell off leaving bare places on the branches. The juniper remained in this condition until December, 1885, when the bare branches showed signs of swelling, and the following spring, April, 1886, telia were produced. More recently, Heald (1907, '09) working with *G. Juniperi-virginianae* (*G. macropus*), the common cedar-apple in eastern North America, has shown by careful observations that it most likely develops in a similar manner. Heald found very young cedar-apples about the size of radish seeds to be present on the cedars in June some days before any mature aeciospores could be detected and this led him to suspect that these young galls were the result of infection from aeciospores of the previous season, and since his observations showed that they did not bear spores until the following spring it seemed most likely that this mycelium must require nearly two years to develop a cedar-apple bearing spores. Observations of the writer substantiate this view.

It would seem, therefore, that whether the mycelium is perennial, *i. e.*, remains alive in the cedar and produces spores for several successive seasons, or whether it dies after having produced a single season's crop, that it may in either case be developing for two years before bearing spores. Further investigations along this line are necessary in order to determine what the nature of the development of the mycelium in the different species really is. Biennial maturation may be the rule in species which have the telia appearng on the twigs or branches, causing hypertrophy, and also in those where the telia develop special outgrowths or gall-like excrescences,

but there are a number of forms where the telia occur on the leaves or young branches in which there is some reason for believing that the maturation is annual, spores developing in the spring from an infection of the previous summer. It is altogether probable that the development of the fungus may not require any definite length of time with respect to the seasons directly, except in so far as it is dependent upon the growth of the host, which is, of course, influenced by the seasonal changes. It is further possible that the time and place of infection may have an influence upon the rate of growth of the mycelium. This is an interesting field in which further experimental data are desirable.

4. Pathologic and Economic Importance

Pathologic Effects

The anatomic changes induced in the host-tissues by the mycelial growth of the species of *Gymnosporangium* are in general more noticeable in the telial than in the aecial hosts. Some of the species, it is true, produce their sori on the leaves of the cedars and junipers without causing material deformations, but the majority of the species cause twig-deformations either of the nature of gradual swellings or of abrupt gall-like swellings. Other species induce malformations of the branch-systems commonly known as witches' brooms. Woernle (1894) has especially investigated the changes induced in the internal morphology of the telial hosts. In the case of *G. clavariaeforme*, which causes gradual fusiform swellings of the branches, he found increased growth in the xylem, phloem, and cortex, the largest increase taking place in the phloem. The medullary rays were found to be more numerous and somewhat higher than usual; the wood parenchyma was more abundant; the tracheides no longer followed a straight course and had numerous intercellular spaces between them. The mycelium filled the phloem and cortical regions and sometimes formed masses in the intercellular spaces. An examination by the same investigator of similar swellings induced by other species of *Gymnosporangium* revealed the same general pathologic effects in the tissues. In most of the hypertrophied areas the limits of the annual growth-rings were difficult to make out, and in the swellings produced by *G. Sabinae* a yellow pigment was found deposited in the walls of all the elements. It is interesting to note that the scar left by the

fall of the spore-masses (telia) is covered by a scar-tissue consisting of several layers of cork-cells, and that the new spore-masses forming in succeeding years rarely break through this cork layer of an old scar but issue through some new portion of the bark. Some of the typical gall-producing forms arise as outgrowths from branches or twigs (as *G. globosum* and *G. Nelsoni*) while others may have their origin in the leaves. *G. Juniperi-virginianae* and *G. floriforme* are examples of species which produce galls that originate in the leaves. Sanford (1888) investigated the changes which are induced in leaf-tissues by the formation of a globoid or reniform gall of *G. Juniperi-virginianae* with the following results: the most striking change is in the great multipication of cells and their generally enlarged size; the cell-walls are thicker than normal and behave toward cytological reagents decidedly like fungous tissue; the vascular system is developed until it is as important as in a branch and divides in a peculiarly radiating manner, the elements of the bundle become distorted and irregularly placed; and the epidermal system of the leaf entirely disappears, its place being taken by layers of cork-cells covered over by a thin layer of dead shrivelled cells.

The aecial phases appear on the leaves, petioles, twigs and fruits of their hosts. Occurrence of the aecia on the leaf blades is usually accompanied by an increased thickness caused by a multiplication of the cells of the spongy parenchyma and the frequent arrangement of the upper ones into palisade-like layers. Fentzling (1892) in examining pear leaves attacked by *G. Sabinae* reported a radial elongation of the cells of the spongy parenchyma and a partial formation of cork. On the other hand Wakker (1892) in an investigation of the twigs of *Crataegus* infected with *G. clavariaeforme* reported that the formation of cork was inhibited, as well as collenchyma, sclerenchyma and chlorophyll. He also found that lignification of the cells of the medullary rays is interfered with, that activity of the intrafascicular cambium is suspended at a very early stage and that interfascicular cambium is not formed. Starch is stored in large quantities in the hypertrophied regions. Some investigators report an increased deposit of calcium oxalate while others find that its formation is diminished. The aecia occurring on some of the smaller fruits, as those of *Crataegus* and *Amelanchier* often occupy the whole of the surface of the fruit. In this case the ovules become completely blighted, the production

of seed being entirely prevented. It is interesting to note that these affected berries show the same abnormal tendency to hang on as do fruit-mummies caused by the attacks of other fungi. On larger fruits such as apples, pears, and quinces the infected area is often only a portion of the surface but the fruit is always dwarfed and often distorted.

The leaf-inhabiting forms, aside from the injury caused by the arrest and utilization of food-materials, may work a still greater injury to the health of the host by bringing about a premature defoliation. In severe infections of apple trees it sometimes happens that the leaves fall before the aecia have time to mature. Heald (1909) reports that in severe cases an ordinary apple leaf may have as many as 200–300 separate points of infection.

Economic Importance

The importance of the members of the apple and cedar families is so great economically that any factors causing disturbances in their health are worthy of consideration. Orchardists have been aware for some time that certain species of rust (*Gymnosporangium*) often attack the stable orchard crops, such as apples, pears, and quinces, in a very virulent and destructive manner. It is not so well appreciated that many of the wild and native species of the apple family which are being used for decorative puposes are also susceptible to rust-diseases, especially when planted in proximity to members of the cedar family. The importance of these rusts from the standpoint of the cedars has, perhaps, been still less appreciated, at any rate it has been much less emphasized. Heald (1907), however, writes "those who have cedars—and there are many in this section [Nebraska] who value them as much as they do their apple trees—have been clamoring for assistance in saving them from the inroads of this fungus [*G. Juniperi-virginianae*]."

From the point of view of the orchard crops there are only a few of the species of *Gymnosporangium* which are of economic importance. *G. Juniperi-virginianae* (*G. macropus*) is the "orchard rust" of American horticultural writers and is the commonest species occurring on apple in this country. It attacks the leaves chiefly but not infrequently the young fruits also become infected. The common aecial hosts of this species are the wild crab-apples, and it is interesting to note in this connection that although the

cultivated apple has been attacked for many years in the eastern United States, it is only in recent years that this fungus has appeared on the cultivated apple in the central states. In discussing an outbreak of apple rust in Iowa during the summer of 1905 Pammel made the following statement, "In my observations and experiments, extending over a period of fourteen years in this state, I have never [before] seen the cultivated apple affected. That it may become a very serious enemy to apple culture in the state cannot be doubted." His prediction has been fulfilled. *G. globosum*, most commonly found on the hawthorns (*Crataegus*), also attacks the leaves of the cultivated apple in the New England states. So far as the writer knows, it has been reported on that host only from Maine, Vermont, Massachusetts, Connecticut and New York. In Europe *G. juniperinum* (*G. tremelloides*) is the only species which attacks the apple. In parts of Europe, especially northward, it is often reported as abundant and severe. Although this species also occurs in America it has not yet been found here on the apple.

The pear (*Pyrus communis*) is occasionally attacked in the eastern United States by *G. globosum* which is usualy confined to the leaves. Stewart (1910), who has had under observation a Kieffer pear orchard on Long Island, N. Y., reports the presence of this rust each year since the trees were planted in 1903 and observes that prior to 1910 only the leaves were affected, while during the season of 1910 both leaves and fruit were severely attacked. *G. Sabinae*, of Europe, has the pear as its chief aecial host and its injury to pear culture there has long been recognized.

In America the quince (*Cydonia vulgaris*) is frequently attacked by *G. germinale* (*G. clavipes*) and more rarely by *G. Nidus-avis*, the former often producing injury of practical importance. Both quinces and pears have occasionally been attacked in Colorado by a roestelia which the writer has referred to *G. Nelsoni*. In Europe *G. clavariaeforme* and *G. Mespili* (*G. confusum*) attack the quince.

From the point of view of the genus *Juniperus* the species of *Gymnosporangium* just mentioned in the foregoing discussion of orchard crops are, perhaps, the more important, since they are the ones which are naturally most likely to occur on those red cedars and junipers which are used for wind breaks or for decorative planting in yards and gardens in the proximity of orchard trees.

There are, however, some species which are more injurious to the cedars than those which have their aecia on economic aecial hosts. *G. Betheli*, common on *Juniperus scopulorum* in the Rocky Mountains, is one of the most destructive species known. The white cedar (*Chamaecyparis thyoides*) is attacked by two species, *G. Botryapites* (*G. biseptatum*) and *G. Ellisii*, the former producing swellings of the trunk and branches and the latter witches' brooms, both often threatening the welfare of the trees.

Control

Methods for the control of these, as well as most other rust-diseases are as yet uncertain or impracticable. Segregation of the members of the apple and cedars families will accomplish the result but is not always possible. In making new plantings, however, this suggestion is worthy of consideration on the part of farmers, orchardists, and landscape gardeners. Spraying as recommended for other fungous diseases has been tried with incomplete success by many different workers. Attempts have been made (1) to prevent teliospore germination by spraying the cedar when the spore-masses were expanded; (2) to prevent infection of the apple by basidiospores (sporidia) by spraying the apple trees just after teliospore germination (*i. e.*, after a rain); and (3) to prevent reinfection of the cedars by spraying them to inhibit aeciospore germination on them when the aeciospores are being distributed in the late summer (see Heald, 1909). Variable results seem to be obtainable depending upon the nature of the season and the judgment of the operator. The first two schemes are open to practical objection not only because spraying is necessitated after every rain for a considerable period in the spring but also because a delay of a few hours after the rain is sufficient to make the spraying useless. The third scheme is apparently an impossibility because of the long period during which spores are being discharged and the lack of any climatic conditions to indicate when distribution is going on. Another suggestion which has been made for the benefit of orchardists concerns the resistance of the varieties grown. This is without doubt deserving of attention as it has been shown (Stevens and Hall, 1910; Stewart, 1910; Lloyd & Ridgway, 1911) that the varieties of apples and pears differ very greatly in their susceptibility. This suggestion may not be so easily followed in practice, however, because the resistant qualities

may not always be combined with other desirable characters. This then might become a problem for the coöperation of the plant breeder. The foregoing statement of the uncertainty and incompleteness of methods for the control of these and similar diseases is but an admission that one of the large problems of the plant pathologist is still unsolved.

PART II

TAXONOMY OF THE GENUS GYMNOSPORANGIUM

5. Introduction

Some of the species of the genus *Gymnosporangium* have been known scientifically since the earliest times. The fungus is said to have been mentioned by Franke in his "Speculum Botanicum" in 1638. It is certain that the description of Micheli's *Puccinia non ramosa* on junipers and cedars given on page 213, and the illustration on plate 92, of his "Nova Plantarum Generum" published in 1729 clearly belong to a species of *Gymnosporangium*. One of the few species of fungi described by Linnaeus in the first edition of the "Species Plantarum" in 1753 was a *Gymnosporangium* although of course not referred to by that name, but as a *Tremella*. Linnaeus had at a still earlier date, 1737, employed the name *Byssus* for these fungi in his "Flora Lapponica."

Much work has been done with the group and many papers have been published referring both to the biology and taxonomy of the species. In more recent years since the subject of phytopathology has been receiving considerable attention a great many notes on the economic importance of the group have appeared. The first study of a monographic nature of the genus was made by Farlow in 1880 in a paper entitled "The Gymnosporangia or Cedar-apples of the United States." This, as the title suggests, attempts to describe only American species. Dietel contributed the part on the Uredinales to Engler & Prantl's "Natürlichen Pflanzenfamilien" in 1897 in which he devoted three pages to the genus *Gymnosporangium*. He recognized 14 species in the world, 8 in North America, 5 in Europe, and 1 in India. In 1901, in a brief paper dealing chiefly with the question of nomenclature Arthur recognized 15 species of cedar-apples, of which he said 8 occurred exclusively in North America, 2 in both North America and Europe, 3 wholly in Europe, 1 in India and 1 in China and Japan. Descriptions of the various species have appeared in Saccardo's "Sylloge

Fungorum" from time to time but both that work and that of Dietel in the "Natürlichen Pflanzenfamilien" while bringing together the systematic information are in nature only compilations. There has therefore been a gradual accumulation of knowledge regarding the genus but no complete monographic study has appeared up to the present time.

As intimated in the prefatory note, this paper attempts to present a systematic treatment of all the species known to occur in any part of the world so far as the writer has been able to make them out from an examination of the literature and herbarium specimens, supplemented by extensive field studies in the United States. The present paper describes 29 species which have the full life-cycle known, 4 known only in the telial phase, and 7 known only in the aecial phase; a total of 40 species.

In preparing the descriptions the author has attempted to make them as brief as possible and still have them include the chief diagnostic characters. If in some instances they appear rather long it is because it is thought best not to sacrifice accuracy for the sake of brevity. Descriptions of the pycnia have been omitted under the different species because as a rule these structures do not present very important diagnostic characters. Pycnia are known in every species where the aecia are known (except *G. bermudianum*), and they have been examined and sectioned but since the characters are fairly uniform* it is thought that the generic description will suffice for this stage. Moreover, even with the fullest descriptions it would be impossible to determine specimens having only this stage present.

In the aecia, the form which the peridium takes on after dehiscence has been used as the chief gross character. Among the microscopic characters of first importance are the nature of the surfaces of the peridial cells and the relative thickness of their walls. The value of the peridial cell in defining the species has been pointed out by Dr. Ed. Fischer (1895), and the writer has also contributed a special paper (1910[2]) on this subject. Concerning the surface characters of the peridial cells it may be well to quote from the latter paper where the descriptive terms to be used are fully explained: "With regard to the surfaces of the peridial

* It is possible to pick out certain species which might show considerable difference in the size of the pycnia, for instance in *G. germinale* they are 160–270μ in diameter by 150–230μ high, with ostiolar filaments 90–150μ long, while in *G. Nidus-avis* they are 120–155μ in diameter by 80–112μ high, with ostiolar filaments 45–65μ long. These are however extreme cases.

cells, it has been found that the species so far recognized divide at first into two classes, one having entirely smooth cells, the other having at least a portion roughened. I have subdivided the latter class upon the nature of the roughness, and have used the terms rugose, verrucose, verruculose, and spinulose to designate the four classes. The terms used to designate the various classes are intended only to be descriptive in a general way. The rugosely sculptured cells are furnished chiefly with ridges or elongated ridge-like papillae in such a way that the effect is that of a surface covered with rugae or folds; the verrucosely marked cells are studded with warty or tubercle-like elevations; the verruculose surfaces are covered with low wart-like protuberances; the spinulose cells have diminutive spines or spicules. The markings always cover the entire inner wall extending to the side walls, in some forms reaching clear across, in others, only a part of the distance, leaving the outer part of the side wall and the entire outer wall, with rare exceptions, smooth."

In the telial stage, the nature of the place where the telia appear is used as a gross character. Some occur on leaves or young branches not producing hypertrophy, others appear on fusiform enlargements of the twigs or branches, while others appear on galls or gall-like excrescences. The form of the telia is also a gross character of prime importance. The color of the mature telia before expansion and germination has been taken account of and is in many instances a good diagnostic character. No matter what the color is originally the telia always become yellowish upon germination. The telia are naked and the microscopic characters therefore lie wholly in the teliospores and pedicels, and consist chiefly of size, number of cells, location and nature of the germ pores, and shape and thickness of the pedicels. It may be said here that it has been pointed out by a number of workers (Körnicke, 1877; Dietel, 1889; Richards, 1889; Blackman, 1904) that some species of this genus possess two sorts of teliospores in every sorus, thick-walled ones and lighter colored thin-walled ones. Generally speaking these do not represent two classes but only two extremes, for all gradations can be found between the thickest walls and the thinnest. No attempt has been made to separate these in the specific descriptions and the measurements given are to be interpreted as the general average, not including, as a rule, either extreme. The theory has been advanced several times that

the thin-walled spores might represent urediniospores but that view cannot be substantiated. It embodies a confused idea of the essential differences between teliospores and urediniospores. If the thin-walled spores put out long undivided germ-tubes as claimed, this must have been due to unusual conditions of growth, for it is well known that under certain special conditions, particularly when growing entirely submerged, the thicker-walled spores, also behave in this way.

6. Generic Description

Order UREDINALES

Family AECIDIACEAE

Genus GYMNOSPORANGIUM Hedw. f.; DC. Fl. Fr. 2: 216. 1805

Cycle of development includes pycnia, aecia, and telia, with distinct alternating phases; heteroecious and autoecious. Pycnia and other sori subepidermal.

Pycnia deep-seated, usually globoid, generally prominent and conspicuous, at first honey-yellow, usually becoming blackish, globose or flattened globose, with ostiolar filaments.

Aecia erumpent, at first cylindric. Peridium dingy white, in a few species short and cupulate but usually elongated into a more or less tubular form, membranous, tending to rupture by longitudinal slits along the sides; peridial cells imbricated and often articulated, occasionally hygroscopic becoming curved when wet, outer walls smooth (except in a few species), rather thin (except in *G. hyalinum*), inner and side walls smooth, verruculose with low wart-like protuberances, verrucose with warty or tubercle-like elevations, rugose with ridges or ridge-like papillae beginning on the inner wall, directed downward and outward and extending obliquely on to the side walls, or spinulose with diminutive spines or spicules, usually rather thick. Aeciospores globoid to broadly ellipsoid, wall colored, verrucose, usually with numerous, scattered, evident germ-pores.

Telia erumpent, naked, usually definite, variously shaped, gelatinous and elastic at maturity, expanding considerably when moistened. Teliospores chiefly 2-celled, in some species 3-, 4- or 5-celled, by transverse septa; walls colored, of varying thickness, smooth; pores usually 2 in each cell, sometimes 1, 3 or 4, variously arranged, often near the septa, sometimes apical in the upper, rarely

near the pedicel in the lower (numerous and scattered in *G. multiporum*); pedicels hyaline, elastic, usually of considerable length, cylindric (carotiform in *G. inconspicuum* and *G. germinale*), walls thick, the outer portions swelling and becoming gelatinized in moisture to form a jelly-like matrix in which the spores appear imbedded.

Type species, *Gymnosporangium conicum* Hedw. f. (said to be on both *Juniperus communis* and *J. sabina*).

7. Analytic Keys

A. Aecia exclusively considered

Heteroecious, aecia inhabiting Malaceae (except Nos. 21 and 24).

Aecia short, cupulate, peridium lacerate or erose.

Aeciospores small (12–23μ), wall thin (1–1.5μ).

1. *G. Blasdaleanum.*

Aeciospores large (23–39μ), wall thick (3–4μ).

2. *G. Sorbi.*

Aecia elongated, tubular at first (except in No. 27), in some species becoming altered by dehiscence.

a Peridium retaining tubular or cornute form, unaltered by dehiscence.

Peridium finally dehiscent at apex, slightly or not at all lacerate along the sides.

Peridial cells verrucose.

Side walls of peridial cells verrucose only on inner third.

4. *G. inconspicuum.*

Side walls of peridial cells verrucose over entire surface.

Aeciospore wall cinnamon-brown.

5. *G. Harknessianum.*

Aeciospore wall pale yellow.

24. *G. gracilens.*

Peridial cells spinulose or subspinulose.

Aeciospores rather large (22–31μ), wall cinnamon-brown.

7. *G. exiguum.*

Aeciospores rather small (17–23μ), wall dingy yellow.

8. *G. Photiniae.*

Peridial cells rugose.

Inner and side walls rather sparsely and coarsely rugose.

Inner and side walls rather thick (7–9μ), aeciospore wall 1.5–2μ thick. 9. *G. Amelanchieris.*

Inner and side walls thick (8–12μ), aeciospore wall 2–2.5μ thick. 10. *G. cornutum.*

Inner and side walls densely and rather finely rugose (5–8μ thick).

Aeciospore wall dark cinnamon-brown, 1.5–2μ thick.

11. *G. Torminali-juniperinum.*

Aeciospore wall light cinnamon-brown, 2–2.5μ thick.

12. *G. Davisii.*

Peridial cells verruculose. 36. *G. Nelsoni.*

Peridium dehiscent with longitudinal slits along the sides, tardily or not at all dehiscent at apex.
Peridial cells subspinulose. 16. *G. trachysorum.*
Peridial cells verrucose.
Aeciospores rather small (18–24μ), wall thin (1–1.5μ). 17. *G. solenoides.*
Aeciospores rather large (20–32μ), wall thick (3–4μ). 37. *G. corniculaus.*
Peridial cells verrucose-rugose 14. *G. juvenescens.*
Peridial cells rugose. 18. *G. tubulatum.*
Peridial cells smooth. 19. *G. Botryapites.*

aa Peridium soon losing tubular form by becoming deeply lacerate or fimbriate.

b Peridium spreading or more or less erect after dehiscence.
Peridial cells rough.
Peridial cells lanceolate in face view (not often seen in side view).
Aeciospores medium-sized (17–28μ).
Aeciospore wall cinnamon-brown, very thick (3–4μ). 20. *G. Nidus-avis.*
Aeciospore wall pale cinnamon-brown, moderately thick (2–2.5μ). 21. *G. exterum.*
Aeciospores large (25–33μ), wall light chestnut-brown. 14. *G. Cunninghamianum.*
Peridial cells rhomboid in side view (not often seen in face view).
Peridial cells verrucose, aeciospores large (21–39μ), wall yellowish. 22. *G. germinale.*
Peridial cells rugose.
Aeciospores small (18–23μ), wall cinnamon-brown. 26. *G. japonicum.*
Aeciospores very large (28–45μ), wall chestnut-brown. 23. *G. juniperinum.*
Peridial cells linear-rhomboid or linear in side view.
Peridial cells verrucose.
Aeciospores small (18–22μ), wall rather thick (1.5–2.5μ). 29. *G. transformans.*
Aeciospores rather large (21–30μ), wall thick (2.5–3.5μ). 30. *G. clavariaeforme.*
Peridial cells verruculose. 31. *G. Yamadae.*
Peridial cells rugose.
Inner and side walls moderately rugose, rather thick (3–6μ).
Aeciospores moderately large (18–30μ), wall rather thick (2.5–3μ). 33. *G. Betheli.*
Aeciospores rather small (15–25μ), wall rather thin (1.5–2μ). 34. *G. globosum.*
Inner and side walls strongly rugose, moderately thick (5–7μ). 28. *G. Mespili.*
Peridial cells smooth. 35. *G. hyalinum.*

bb Peridium strongly revolute after dehiscence.
Peridial cells somewhat curved when wet, side walls closely rugose nearly to outer side. 38. *G. floriforme.*
Peridial cells strongly curved when wet, side walls rather sparsely rugose on inner half. 39. *G. Juniperi-virginianae.*
aaa Peridium balaniform, rupturing along the sides, peridial cells rugose. 27. *G. Sabinae.*
Autoecious, aecia elongated, appearing on galls like the telia, peridium soon lacerate, peridial cells rugose. 40. *G. bermudianum.*

B. Telia exclusively considered

Telia appearing on the leaves or young branches, not causing material hypertrophy (except in Nos. 9 and 11).
Telia not causing fasciation of the branches.
Telia pulvinate, low.
Teliospores 2–5-celled, pedicels terete. 1. *G. Blasdaleanum.*
Teliospores 2-celled.
Pedicels of teliospores terete. 3. *G. fraternum.*
Pedicels of teliospores carotiform. 4. *G. inconspicuum.*
Telia musciform. 6. *G. multiporum.*
Telia tongue-shaped. 7. *G. exiguum.*
Telia applanate (causing slight fusiform swellings). 9. *G. Amelanchieris.*
Telia hemispheric.
Teliospores with hyaline papillae over the germ-pores.
Teliospores rather small (31–42μ long), papillae often not conspicuous (2–5μ). 10. *G. cornutum.*
[Telia also on fusiform swellings of branches—see below.]
Teliospores medium-sized (35–49μ long); papillae noticeable (3–6μ). 11. *G. Torminali-juniperinum.*
Teliospores rather large (40–55μ long), papillae large (4–7μ). 12. *G. Davisii.*
Teliospores without hyaline papillae over the germ-pores, large (56–72μ long). 13. *G. Cunninghamianum.*
Telia causing fasciation of the branches, or witches' brooms.
Telia cinnamon-brown, teliospores ellipsoid, medium-sized (39–52μ long). 14. *G. juvenescens.*
Telia reddish-brown, teliospores narrowly ellipsoid, large (55–74μ long). 15. *G. Kernianum.*
Telia appearing on twigs or branches, causing more or less hypertrophy.
Enlargements abruptly fusiform, short, telia wedge-shaped. 16. *G. trachysorum.*
Enlargements irregularly fusiform and knot-like, telia pulvinate. 17. *G. solenoides.*
Enlargements gradually fusiform, long.
Telia hemispheric, usually small and definite.
Teliospores 2–4-celled, pedicels terete. 19. *G. Botryapites.*

Teliospores 2-celled.
Pedicels of teliospores terete. 20. *G. Nidus-avis.*
Pedicels of teliospores carotiform. 22. *G. germinale.*
Telia applanate or pulvinate, usually large and somewhat indefinite
Teliospores with hyaline papillae over the germ-pores.
10. *G. cornutum.*
Teliospores without hyaline papillae over the germ-pores.
Teliospores rather small (32–42μ long).
21. *G. exterum.*
Teliospores rather large (42–61μ long).
23. *G. juniperinum.*
Telia cristiform, irregularly crenate above.
24. *G. gracilens.*
Telia wedge-shaped, often irregular and lacunose.
Teliospores medium-sized (42–55μ long).
25. *G. effusum.*
Teliospores rather large (57–66μ long).
26. *G. japonicum.*
Telia conic or often laterally compressed.
Teliospores slightly constricted, usually narrowed both above and below. 27. *G. Sabinae.*
Teliospores mostly not constricted, usually rounded at apex.
28. *G. Mespili.*
Telia terete or cylindric.
Telia stout, teliospores 2-celled. 30. *G. clavariaeforme.*
Telia slender, teliospores 2–5-celled. 32. *G. Ellisii.*
Telia often causing fasciation of the branches or witches' brooms.
Telia hemispheric, spores 2-celled. 20. *G. Nidus-avis.*
Telia terete, spores 2–5-celled. 32. *G. Ellisii.*
Telia appearing on galls or gall-like excrescences.
Galls very irregular, usually elongated and knot-like, often in succession along a branch. 33. *G. Betheli.*
Galls globoid or reniform.
Telia laterally compressed.
Telia thick, wedge-shaped, chestnut-brown.
34. *G. globosum.*
Telia thin, irregularly flattened, light chestnut-brown.
36. *G. Nelsoni.*
Telia terete.
Telia somewhat conic, chestnut-brown.
Teliospores with slight hyaline thickenings over the germ-pores.
37. *G. corniculans.*
Teliospores without hyaline thickenings over the germ-pores.
38. *G. floriforme.*
Telia cylindric or cylindric-acuminate, golden-brown.
39. *G. Juniperi-virginianae.*
Telia pulvinate, low, inconspicuous. 40. *G. bermudianum.*

8. Host Keys

A. Hosts harboring aecial phase

a. Order Rosales, family Malaceae (Pomaceae)

Crataegus:

Aecia short, cupulate, peridium lacerate or erose. 1. *G. Blasdaleanum.*

Aecia elongated, tubular at first, in some species altered by dehiscence.

Peridium retaining tubular or cornute form.

Peridium finally dehiscent at apex, slightly or not at all lacerate along sides. 7. *G. exiguum.*

Peridium dehiscent with longitudinal slits along the sides.

Peridial cells subspinulose. 16. *G. trachysorum.*

Peridial cells rugose. 18. *G. tubulatum.*

Peridium soon losing tubular form by becoming deeply lacerate or fimbriate.

Peridium spreading or more or less erect after dehiscence.

Peridial cells rough.

Peridial cells verrucose.

Aeciospore wall pale yellow, coarsely verrucose. 22. *G. germinale.*

Aeciospore wall cinnamon-brown, moderately verrucose. 30. *G. clavariaeforme.*

Peridial cells rugose.

Inner and side walls moderately rugose, rather thick (3–6μ).

Aeciospores moderately large (18–30μ), wall rather thick (2.5–3μ). 33. *G. Betheli.*

Aeciospores rather small (15–25μ), wall rather thin (1.5–2μ). 34. *G. globosum.*

Inner and side walls strongly rugose, moderately thick (5–7μ). 28. *G. Mespili.*

Peridial cells smooth. 35. *G. hyalinum.*

Peridium strongly revolute. 38. *G. floriforme.*

Amelanchier:

Aecia short, cupulate, peridium lacerate or erose. 1. *G. Blasdaleanum.*

Aecia elongated, tubular at first, in some species altered by dehiscence.

Peridium retaining tubular or cornute form.

Peridium finally dehiscent at apex, slightly or not at all lacerate along sides.

Peridial cells verrucose.

Side walls of peridial cells verrucose only on inner third. 4. *G. inconspicuum.*

Side walls of peridial cells verrucose over entire surface. 5. *G. Harknessianum.*

Peridial cells rugose. 9. *G. Amelanchieris.*
Peridial cells verruculose. 36. *G. Nelsoni.*
Peridium dehiscent with longitudinal slits along the sides.
Peridial cells verrucose. 37. *G. corniculans.*
Peridial cells verrucose-rugose. 14. *G. juvenescens.*
Peridial cells smooth. 19. *G. Botryapites.*
Peridium soon losing tubular form by becoming lacerate and more or less spreading.
Peridial cells rugose. 20. *G. Nidus-avis.*
Peridial cells verrucose.
Aeciospore wall pale yellow, coarsely verrucose. 22. *G. germinale.*
Aeciospore wall cinnamon-brown, moderately verrucose. 30. *G. clavariaeforme.*

PYRUS:

Aecia elongated, tubular at first, soon altered by becoming deeply lacerate or fimbriate.
Peridium soon losing tubular form by becoming deeply lacerate or fimbriate.
Peridial cells lanceolate in face view (not often seen in side view), aeciospores large (25–33μ). 13. *G. Cunninghamianum.*
Peridial cells rhomboid in side view (not often seen in face view), aeciospores small (18–23μ). 26. *G. japonicum.*
Peridial cells linear-rhomboid in side view.
Peridial cells verrucose. 30. *G. clavariaeforme.*
Peridial cells rugose.
Inner and side walls moderately rugose, moderately thin (3–5μ). 34. *G. globosum.*
Inner and side walls strongly rugose, rather thick (5–7μ). 28. *G. Mespili.*
Peridium retaining tubular form, peridial cells verruculose. 36. *G. Nelsoni.*
Aecia elongated, balaniform, rupturing along the sides, apex remaining bluntly conic. 27. *G. Sabinae.*

MALUS:

Aecia short, cupulate, peridium lacerate or erose. 2. *G. Sorbi.*
Aecia elongated, tubular at first, in some species becoming altered by dehiscence.
Peridium spreading or more or less erect after dehiscence.
Peridial cells verruculose. 31. *G. Yamadae.*
Peridial cells verrucose. 22. *G. germinale.*
Peridial cells rugose.
Aeciospores rather small (15–25μ), wall rather thin (1.5–2μ). 34. *G. globosum.*
Aeciospores very large (28–45μ), wall very thick (3–5μ). 23. *G. juniperinum.*
Peridium strongly revolute, peridial cells strongly curved when wet. 39. *G. Juniperi-virginianae.*

SORBUS:

Aecia short, cupulate, peridium lacerate or erose.
2. *G. Sorbi.*

Aecia elongated, tubular at first, in some species becoming altered by dehiscence.

Peridium retaining tubular or cornute form, unaltered by dehiscence.

Peridial cells rugose.

Inner and side walls densely rugose, moderately thick (6–7μ).
11. *G. Torminali-juniperinum.*

Inner and side walls moderately rugose, thick (8–12μ).
10. *G. cornutum.*

Peridial cells verrucose. 17. *G. solenoides.*

Peridium losing tubular form by dehiscence, spreading or erect.

Aeciospores medium small (15–25μ), wall rather thin (1.5–2μ).
34. *G. globosum.*

Aeciospores very large (28–45μ), wall very thick (3–5μ).
23. *G. juniperinum.*

ARONIA:

Aecia elongated, tubular at first, in some species becoming altered by dehiscence.

Peridium retaining tubular or cornute form.
12. *G. Davisii.*

Peridium spreading or more or less erect after dehiscence.

Peridial cells rhomboid in side view (45–95μ long), aeciospore wall coarsely verrucose. 22. *G. germinale.*

Peridial cells linear-rhomboid in side view (80–130μ long), aeciospore wall moderately verrucose. 30. *G. clavariaeforme.*

Peridial cells linear in side view (150–300μ long), aeciospore wall, finely verrucose. 29. *G. transformans.*

CYDONIA:

Aecia elongated, tubular at first, becoming altered by dehiscence.

Peridial cells verrucose.

Aeciospore wall pale yellow, coarsely verrucose.
22. *G. germinale.*

Aeciospore wall cinnamon-brown, moderately verrucose.
30. *G. clavariaeforme.*

Peridial cells verruculose. 36. *G. Nelsoni.*

Peridial cells rugose.

Inner and side walls strongly rugose with ridges of varying length.
28. *G. Mespili.*

Inner and side walls rugose with long narrow ridges interspersed with roundish papillae. 20. *G. Nidus-avis.*

COTONEASTER:

Aecia elongated, tubular at first, becoming altered by dehiscence.

Peridial cells verrucose. 30. *G. clavariaeforme.*

Peridial cells rugose. 28. *G. Mespili.*

PERAPHYLLUM:
Aecia elongated, retaining tubular form, peridial cells verruculose.
36. *G. Nelsoni.*

MESPILUS:
Aecia elongated, tubular at first, becoming altered by dehiscence, peridial cells rugose. 28. *G. Mespili.*

POURTHIAEA:
Aecia short, cupulate, peridium lacerate or erose.
(?) 1. *G. Blasdaleanum.*
Aecia elongated, retaining tubular form after dehiscence, peridial cells subspinulose. 8. *G. Photiniae.*

b. Order Rosales, family Rosaceae

PORTERANTHUS:
Aecia elongated, altered by dehiscence, becoming lacerate almost to base, peridial cells rugose. 21. *G. exterum.*

c. Order Rosales, family Hydrangiaceae

FENDLERA:
PHILADELPHUS:
Aecia elongated, remaining tubular after dehiscence, peridial cells verrucose over entire surface. 24. *G. gracilens.*

d. Order Pinales, family Juniperaceae

JUNIPERUS:
Aecia elongated, appearing on galls like the telia, peridium soon lacerate, peridial cells rugose. 40. *G. bermudianum.*

B. HOSTS HARBORING TELIAL PHASE, ORDER PINALES, FAMILY JUNIPERACEAE

JUNIPERUS:
§ SABINA (genus SABINA).
Telia appearing on the leaves or young branches, not causing material hypertrophy.
Telia not causing fasciation of the branches.
Telia pulvinate, reddish-brown. 4. *G. inconspicuum.*
Telia musciform, chestnut-brown. 6. *G. multiporum.*
Telia tongue-shaped, chestnut-brown. 7. *G. exiguum.*
Telia causing fasciation of the branches, or witches' brooms.
Telia cinnamon-brown, teliospores ellipsoid, medium (39–52μ long). 14. *G. juvenescens.*
Telia reddish-brown, teliospores narrowly-ellipsoid, large (55–74μ). 15. *G. Kernianum.*
Telia appearing on twigs or branches, causing more or less hypertrophy.
Enlargements abruptly fusiform, short, telia wedge-shaped. 16. *G. trachysorum.*
Enlargements gradually fusiform, long.
Telia hemispheric.

Pedicels of teliospores terete. 20. *G. Nidus-avis.*
Pedicels of teliospores carotiform. 22. *G. germinale.*
Telia applanate or pulvinate. 21. *G. exterum.*
Telia cristiform. 24. *G. gracilens.*
Telia wedge-shaped, often irregular and lacunose.
Teliospores medium-sized (42–55μ long). 25. *G. effusum.*
Teliospores rather large (57–66μ long). 26. *G. japonicum.*
Telia conic or often compressed laterally.
Teliospores slightly constricted, usually narrowed both above and below. 27. *G. Sabinae.*
Teliospores mostly not constricted, usually rounded at apex. 28. *G. Mespili.*
Telia often causing fasciation of the branches, or witches' brooms. 20. *G. Nidus-avis.*
Telia appearing on galls or gall-like excrescences.
Galls very irregular, usually elongated and knot-like, often in succession along a branch. 33. *G. Betheli.*
Galls globoid or reniform, solitary.
Telia laterally compressed.
Telia thick, wedge-shaped, chestnut-brown. 34. *G. globosum.*
Telia thin, irregularly flattened, light chestnut-brown. 36. *G. Nelsoni.*
Telia terete.
Telia somewhat conic, chestnut-brown.
Teliospore wall with slight hyaline thickenings over the germ-pores. 37. *G. coniculans.*
Teliospore wall uniform, without hyaline thickenings. 38. *G. floriforme.*
Telia cylindric or cylindric-acuminate, golden-brown. 39. *G. Juniperi-virginianae.*
Telia pulvinate, low, inconspicuous. 40. *G. bermudianum.*

JUNIPERUS:
§ OXYCEDRUS (true JUNIPERUS).
Telia appearing on the leaves or young branches, with little or no hypertrophy.
Telia applanate, teliospores without hyaline papillae over the germ-pores. 9. *G. Amelanchieris.*
Telia hemispheric, teliospores with hyaline papillae over the germ-pores.
Teliospores rather small (31–42μ long), papillae often not conspicuous (2–5μ). 10. *G. cornutum.*
Teliospores medium-sized (35–49μ long), papillae noticeable (3–6μ). 11. *G. Torminali-juniperinum.*
Teliospores rather large (40–55μ long), papillae large (4–7μ). 12. *G. Davisii.*

Telia appearing on twigs or branches, causing more or less hypertrophy.
Telia hemispheric, usually small and definite.
22. *G. germinale.*
Telia applanate or pulvinate, usually large and somewhat indefinite.
Teliospores with hyaline papillae over the germ pores.
10. *G. cornutum.*
Teliospores without hyaline papillae over the germ pores.
23. *G. juniperinum.*
Telia terete or cylindric. 30. *G. clavariaeforme.*

CHAMAECYPARIS:

Telia appearing on the leaves, not causing hypertrophy, teliospores 2-celled.
3. *G. fraternum.*
Telia appearing on the twigs or branches causing more or less hypertrophy.
Enlargements gradually fusiform, surface rather regular.
Telia hemispheric, teliospores 2–4-celled.
19. *G. Botryapites.*
Telia terete, slender, teliospores 2–5-celled.
32. *G. Ellisii.*
Enlargements irregular, knotty, surface rough, teliospores 2–3-celled.
17. *G. solenoides.*
Telia often causing fasciation of the branches, or witches' brooms.
32. *G. Ellisii.*

CUPRESSUS:

Telia appearing on the smaller branches, with little or no hypertrophy, telia hemispheric, teliospores 2-celled. 13. *G. Cunninghamianum.*

HEYDERIA:

Telia appearing on the leaves, not causing hypertrophy, teliospores 2–5-celled. 1. *G. Blasdaleanum.*

9. Specific Descriptions

1. **Gymnosporangium Blasdaleanum** (Diet. & Holw.)

Aecidium Blasdaleanum Diet. & Holw. Erythea **3**: 77. 1895.
Phragmidium Libocedri P. Henn. Hedw. **37**: 271. 1898.
?*Aecidium Pourthiaeae* Sydow, Mem. Herb. Boiss. **4**: 3. 1900.
Gymnosporangium aurantiacum Sydow, Ann. Myc. **2**: 28. 1904.
Gymnosporangium Libocedri Kern, Bull. Torrey Club **35**: 509. 1908.

Aecia hypophyllous and fruiticolous, in crowded groups 1–5 mm. across, cupulate, low, 0.2–0.3 mm. in diam.; peridium delicate, margin lacerate, spreading or somewhat recurved; peridial cells rhomboid in side view, 18–23μ long, outer wall 3–4μ thick, transversely striate, smooth, inner and side walls about half as thick, verrucose; aeciospores globoid, 12–20$\times$14–23μ, wall pale yellow, rather thin, 1–1.5μ, finely verrucose.

Telia foliicolous, not causing noticeable distortions, scattered, roundish-oval, about 0.8–1.5 mm. across, pulvinate, reddish-brown,

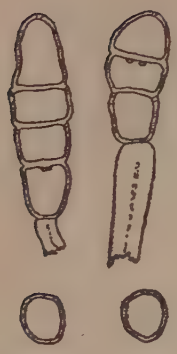


Fig. 2.* *G. Blasdaleanum.*

ruptured epidermis not noticeable; teliospores 2–5-celled, linear-oblong, 19–30 × 35–87 μ, slightly constricted at the septa, wall pale brown, thin, 1μ; pedicels cylindric, often large, 7–25μ in diam.; pores 2, except in upper cell, apical.

Host plants:

For the aecia: *Amelanchier alnifolia* Nutt., *A. florida* Lindl., *A. pallida* Greene, *Crataegus Douglasii* Lindl. (*C. brevispina* Dougl.), *C. rivularis* Nutt., ?*Pourthiaea villosa* (Thunb.) Dec. (*Photinia villosa* DC.).

For the telia: *Heyderia decurrens* (Torr.) K. Koch. (*Libocedrus decurrens* Torr.).

Type locality: Shasta Springs, Siskiyou Co., Calif., on *Crataegus rivularis*.

Distribution: Pacific slope of the United States from Oregon southward into northern California; possibly also in Japan (*Aecidium Pourthiaeae* Sydow).

Exsiccati: Sydow, Ured. *1149, 1786;* Ellis & Ev., N. Am. Fungi *3248*.

2. **Gymnosporangium Sorbi** (Arth.)

? *Uredo nootkatensis* Trel. Harriman Alaska Exped. **5**: 36. 1904.
Aecidium Sorbi Arth. Bull. Torrey Club **33**: 521. 1906.

Aecia hypophyllous, in small groups of 4–7 on discolored thickened spots, or often more numerous on larger swellings on the veins or rachis, cupulate, 0.2–0.4 mm. high, 0.2–0.3 mm. in diam.; peridium colorless, margin nearly erect, erose; peridial cells rhomboid in side view, 30–45μ long, outer wall thick, 10–13μ, transversely striate, smooth, inner and side walls thinner, 3–5μ, verrucose; aeciospores broadly ellipsoid, 23–27×27–39μ, wall pale yellow, thick, 3–4μ, minutely verrucose.

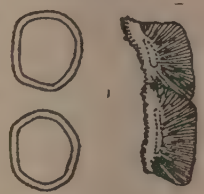


Fig. 3. *G. Sorbi.*

Telia unknown.

*This and the following text-figures are all made to the same scale. Teliospores and side views of peridial cells have been chiefly employed for these illustrations. A few drawings of aeciospores are included. For further details see Explanation of Illustrations (text-figures), p. 480.

HOST PLANTS:

For the aecia: *Malus rivularis* (Doug.) Roem., *Sorbus occidentalis* (Wats.) Greene, *S. scopulina* Greene.

For the telia: unknown, possibly *Chamaecyparis nootkatensis*.

TYPE LOCALITY: Hodag Lake, Vancouver Island, B. C., on *Sorbus occidentalis*.

DISTRIBUTION: Along the Pacific coast of the United States from Alaska southward into Washington.

3. **Gymnosporangium fraternum** sp. nov.

Aecia unknown.

Telia foliicolous, solitary, scattered, oval, 0.8–2 mm. across, pulvinate, chestnut-brown, ruptured epidermis noticeable; teliospores 2-celled, ellipsoid, 16–19× 39–48μ, rounded above, narrowed below, slightly constricted at the septum, wall cinnamon-brown, medium, 1.5–2.5μ, thicker above, 3–5μ; pedicels cylindric, 5–6μ in diam.; pores 2 in each cell, near the septum.

FIG. 4. *G. fraternum*.

HOST PLANTS:

For the aecia: unknown.

For the telia: *Chamaecyparis thyoides* (L.) B.S.P. (*Cupressus thyoides* L., *Chamaecyparis sphaeroidea* Spach.)

Type collected at Newfield, N. J., on *Chamaecyparis thyoides*, April, 1880, *J. B. Ellis* (Ellis & Ev. N. Am. Fungi *1479*—host erroneously determined as *Thuja occidentalis*).

DISTRIBUTION: Small area along the Atlantic coast from Massachusetts to New Jersey.

EXSICCATI: Seym. & Earle, Econ. Fungi *244;* Ellis, N. Am. Fungi *1479;* Roum. Fungi Sel. *4886.*

The form which is here recognized as a species was given subspecific rank in 1885 by Farlow in Ellis, N. Am. Fungi *1479*, under the name *G. biseptatum foliicolum*, without any accompanying description. The writer has made several unsuccessful attempts to cultivate this form and culture evidence is therefore lacking to support its standing as a distinct species. Its habit and morphological characters are however so distinct from *G. Botryapites* (*biseptatum*), the only species with which it appears to be at all allied, that the writer feels justified in recognizing it as a good species.

4. Gymnosporangium inconspicuum Kern, Bull. Torrey Club **34**: 461. 1907

Roestelia Harknessianoides Kern, Bull. Torrey Club **34**: 463. 1907.

Aecia chiefly fruiticolous, scattered irregularly or crowded, cylindric, 0.5–0.8 mm. in diameter by 2–4 mm. high; peridium rather tough, rupturing at apex, not becoming lacerate along the sides, remaining tubular; peridial cells seen in both face and side views, polygonal-oblong in face view, 25–35×65–100μ, rhomboid in side view, thick, 45–55μ, outer wall moderately thick 5–8μ, smooth, inner wall very thick, 27–35μ, moderately and closely verrucose with slightly irregular papillae, side walls verrucose only on inner third similar to inner wall; aeciospores globoid, 23–27 ×25–31μ, wall pale yellow, 2–2.5μ thick, finely verrucose.

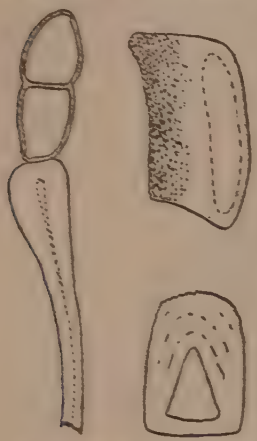


Fig. 5. *G. inconspicuum.*

Telia caulicolous, usually arising between the scale-like leaves on the green branches, usually causing a yellowing of the leaves, more rarely on the woody branches, scattered or aggregated and often confluent about the entire margins of several adjacent scale-like leaves, pulvinate, oblong, 0.4–1 mm. wide, 0.5–1 mm. high, reddish-brown; teliospores 2-celled, oblong-ellispoid, 25–29 ×55–80μ, often acutish at apex, obtuse below, not or only slightly constricted at the septum, wall thin, about 1μ, golden yellow; pedicel cariotiform; swelling greatly next to the spore, 25–65μ; pores one in each cell, apical in the upper, near the pedicel in the lower.

Host plants:

For the aecia: *Amelanchier alnifolia* Nutt., *A. oreophila* A. Nels., *A. utahensis* Koehne.

For the telia: *Juniperus utahensis* (Engelm.) Lemm. (*Sabina utahensis* Rydb.).

Type locality: Glenwood Springs, Colorado, on *Sabina utahensis*.

Distribution: In the mountains of western Colorado, Utah, and New Mexico.

Illustrations: Bot. Gaz. **49**: *pl. 22, f. 15;* Mycologia **3**: 158, *f. id.*

Exsiccati: Ellis & Ev. Fungi Columb. *1293*.

5. **Gymnosporangium Harknessianum** (Ellis & Ev.)

Roestelia Harknessiana Ellis & Ev.; Kern, Bull. Torrey Club **34**: 462. 1907.

Aecia chiefly fruiticolous, evenly disposed, cylindric, 0.5–0.8 mm. in diameter, 4–7 mm. long; peridium tough, dehiscent at apex, not becoming lacerate along the sides, remaining tubular; peridial cells seen in both face and side views, polygonal-oblong in face view, 40–65 × 90–112μ, rhomboid in side view, 58–74 μ thick, outer wall moderately thick, 4–6 μ, smooth, inner wall thick, 15–20μ, coarsely verrucose with roundish or slightly irregular papillae, side walls verrucose over the entire surface similar to the inner wall, papillae slightly less crowded toward outer wall; aeciospores globoid, 22–26 × 26–30μ, wall light cinnamon-brown, 2–2.5μ thick, finely verrucose.

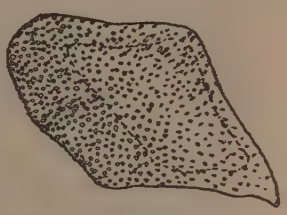


Fig. 6. *G. Harknessianum.*

Telia unknown.

Host plants:

For the aecia: *Amelanchier alnifolia* Nutt.

For the telia: unknown.

Type locality: Klamath River, California, on *Amelanchier alnifolia.*

Distribution: Known only from type locality.

Illustration: Bot. Gaz. **49**: *pl. 22, f. 16.*

Exsiccati: Ellis & Ev. N. Am. Fungi *2714.*

6. Gymnosporangium multiporum Kern, Mycologia **1**: 210. 1909

Aecia unknown.

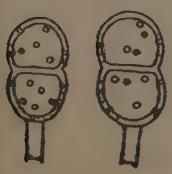


Fig. 7. *G. multiporum.*

Telia caulicolous, arising between the scale-like leaves on the green twigs, scattered or aggregated and confluent, musciform, 0.5–1 mm. across by 0.5–0.8 mm. high, light chestnut-brown; teliospores 2-celled, ellipsoid, 20–24×45–51μ, rounded both above and below, considerably constricted at the septum, wall light cinnamon-brown, 1.5–2.5μ thick; pedicel cylindric; pores 5–7 in each cell, large, scattered.

HOST PLANTS:

For the aecia: unknown.

For the telia: *Juniperus monosperma* (Engelm.) Sarg. (*Sabina monosperma* Rydb.), *Juniperus utahensis* (Engelm.) Lemm. (*Sabina utahensis* Rydb.).

TYPE LOCALITY: Trinidad, Colorado, on *Sabina monosperma*.

DISTRIBUTION: Southern Colorado.

ILLUSTRATION: Mycologia **1**: 209, *f. 2;* **3**: 158, *f. 1b.*

7. GYMNOSPORANGIUM EXIGUUM Kern, Bull. Torrey Club **35**: 508. 1908

Aecia hypophyllous and fruiticolous, rather sparsely arranged in irregular groups, causing considerable hypertrophy of the veins, petioles, or fruits, cylindric, 2–3 mm. high by 0.3–0.4 mm. in diameter; peridium rupturing at apex, margin not splitting much, erect, peridial cells usually seen in face view, very broadly lanceolate, 29–40×70–90μ, oblong in side view, 25–30μ thick, outer wall thin, about 3μ, very closely spinulose, inner and side walls thick, 9–14μ, sculptured like the outer wall but with longer papillae (up to 6μ long); aeciospores globoid or broadly ellipsoid, 22–25×26–31μ, wall cinnamon-brown, 2–3μ thick, finely verrucose.

FIG. 8. *G. exiguum.*

Telia foliicolous, scattered, tongue-shaped or conic, small, 0.5–1 mm. thick by 1–1.5 mm. high, chestnut-brown; teliospores 2-celled, ellipsoid, 18–23×45–55μ, rounded or slightly narrowed both above and below, slightly or not constricted at the septum, wall pale cinnamon-brown, rather thin, about 1.5μ; pores 2 in each cell near the septum.

HOST PLANTS:

For the aecia: *Crataegus Tracyi* Ashe.

For the telia: *Juniperus mexicana* Spreng. (*Cupressus sabinioides* H.B.K., *J. sabinoides* Nees.), *J. pachyphlaea* Torr. (*Sabina pachyphlaea* Antoine), *J. virginiana* L. (*Sabina virginiana* Antoine).

TYPE LOCALITY: Fredericksburg, Texas, on *Sabina virginiana*.

DISTRIBUTION: Central and western Texas.

ILLUSTRATION: Bot. Gaz. **49**: *pl. 22, f. 17.*

EXSICCATI: Barth. N. Am. Ured. 7.

8. **Gymnosporangium Photiniae** (P. Henn.)

Roestelia Photiniae P. Henn. Hedwigia **33**: 231. 1894.

Aecia hypophyllous, gregarious, numerous, in crowded groups on thickened spots, cylindric, 0.2–0.4 mm. in diameter by 3–4 mm. high; peridium rupturing at apex, remaining tubular, becoming somewhat cancellate in upper part; peridial cells seen in both side and face views, oblong in side view, 23–29 × 61–93 μ, lanceolate in face view, 25–35μ broad, outer wall rather thin, 2–3μ, inner and side walls rather thick, 5–7μ, densely and rather sharply subspinulose; aeciospores broadly ellipsoid or globoid, 17–18 × 19–23 μ, wall dingy yellow, moderately thick, 2.5–3.5 μ, evenly and moderately verrucose.

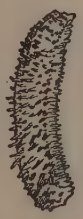


Fig. 9. *G. Photiniae.*

Telia unknown.

Host plants:

For the aecia: *Pourthiaea villosa* (Thunb.) Dec. (*Photinia villosa* Dec., *Photinia laevis* DC.).

For the telia: unknown.

Type locality: Yokohama, Japan, on *Photinia laevis.*

Distribution: Japan.

9. Gymnosporangium Amelanchieris (DC.) Ed. Fisch. Zeits. f. Bot. **1**: 711. 1909

Aecidium Amelanchieris DC. Fl. Fr. **6**: 97. 1815.
Centridium mamillosum Chev. Fl. Env. Paris **1**: 383. 1826.
Centridium Amelanchieris Desm. Pl. Crypt. *1377.* 1845.
Roestelia Amelanchieris Roum. Fungi Gall. *2732.* 1884.

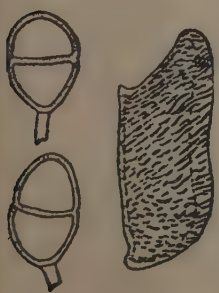


Fig. 10. *G. Amelanchieris.*

Aecia hypophyllous, in small groups, borne in gall-like, frustum-shaped protuberances which are often coalescent, cylindric, 0.3–0.5 mm. in diameter by 3–5 mm. high; peridium finally dehiscent at apex, becoming somewhat split along the sides; peridial cells usually seen in side view, rhomboid, 29–39 by 80–100μ, moderately rugose on inner and side walls, with ridge-like papillae of varying length, outer wall rather thin, 2–3μ, inner and side walls rather thick, 7–9μ; aeciospores broadly ellipsoid or globoid, 19–23 × 25–29μ, wall light chestnut-brown, 1.5–2μ thick, finely verrucose.

Telia chiefly caulicolous, appearing on slight fusiform swellings of the smaller branches, applanate, indefinite, varying in size, 3–5 mm. across, chestnut-brown; teliospores 2-celled, very broadly ellipsoid, 23–39×45–56μ, usually rounded both above and below; slightly or not constricted at the septum, wall light chestnut-brown, 1.5–2μ thick, without hyaline thickenings over the germ-pores; pores 1 or 2 in each cell, apical or near the septum.

HOST PLANTS:

For the aecia: *Amelanchier ovalis* Medic. (*A. vulgaris* Moench., *Aronia rotundifolia* Pers.).

For the telia: *Juniperus communis* L. [*J. sibirica* Burgsd.].

TYPE LOCALITY: Jura, France, on *Amelanchier* [*vulgaris*].

DISTRIBUTION: Europe.

ILLUSTRATIONS: Zeits. f. Bot. **1**: *f.* 7.

EXSICCATI: Sydow, Ured. *2287;* Allesch. & Schn. Fungi Bav. *514;* Roum. Fungi Gall. *2732;* Desm. Pl. Crypt. Fr. *1377;* Briosi & Cavara, Funghi Paras. *162;* Sacc. Myc. Ven. *399;* Sacc. Myc. Ital. *1097, 1257;* Rab.-Paz. Fungi Eur. *4112.*

10. GYMNOSPORANGIUM CORNUTUM (Pers.) Arth. Mycologia **1**: 240. 1909

Aecidium cornutum Pers. in J. F. Gmel. Syst. Nat. **2**: 1472. 1791.
Caeoma cornutum Schlecht. Fl. Berol. **2**: 111. 1824.
Caeoma cylindrites Link, in Willd. Sp. Pl. **6**²: 64. 1825.
Gymnosporangium Juniperi Link, in Willd. Sp. Pl. **6**²: 127. 1825.
Centridium Sorbi Chev. Fl. Env. Paris **1**: 383. 1826.
Gymnosporangium aurantiacum Chev. Fl. Env. Paris **1**: 424. 1826.
Roestelia cornutum Fries, Sum. Veg. Scand. **2**: 510. 1849.
Ceratitium cornutum Rabenh. Bot. Zeit. **9**: 452. 1851.
Podisoma juniperinum Oersted, Overs. Danske Vid. Selsk. Forh. **1866**: 191. 1866.

Aecia chiefly hypophyllous, in irregular or annular groups 3–10 mm. across, on thickened discolored areas, cylindric, somewhat attenuated above, acute at apex, 3–5 mm. high, 0.4–0.6 mm. in diameter; peridium rupturing rather tardily at apex, becoming somewhat but not deeply lacerate; peridial cells seen in both face and side views, broadly lanceolate in face view, 19–29×60–110μ, rhomboid in side view, 30–35μ thick, outer wall thin, 2μ, smooth, inner and side walls thick, 8–12μ, moderately rugose with short ridge-like papillae; aeciospores globoid, 18–25×21–29μ, wall light chestnut-brown, 2–2.5μ thick, rather finely verrucose.

Telia chiefly caulicolous, usually appearing on slight fusiform

enlargements of the smaller woody branches, occasionally appearing on the leaves also, scattered, solitary or often aggregated and confluent, irregular, varying greatly in size, 1–3 mm. across, applanate and low or somewhat pulvinate, light chocolate-brown, teliospores 2-celled, broadly ellipsoid, 16–22×31–42μ, usually narrowed below, rounded or attenuated at the apex, sometimes enlarged near the septum in one or two places owing to the presence of hyaline papillae over the germ-pores, not or only rarely constricted at the septum, wall light cinnamon-brown, thin, about 1μ, papillae 2–5μ; pores 1–2 in each cell, apical or near the septum.

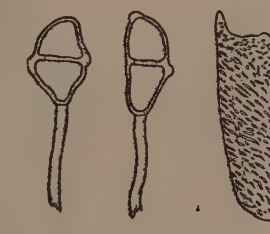


FIG. 11. *G. cornutum.*

HOST PLANTS:

For the aecia: *Sorbus americana* Marsh., *S. Aucuparia* L., *S. hybrida* L. (= *S. Aria* × *aucuparia*), *S. scopulina* Greene (*S. sambucifolia* A. Gray not C. & S.).

For the telia: *Juniperus communis* L., *J. sibirica* Burgsd. (*J. nana* Willd.).

TYPE LOCALITY: Norway, on *Sorbus aucuparia.*

DISTRIBUTION: Greenland south to New York and Wisconsin, and in the mountains of Wyoming and Colorado; and in Europe.

ILLUSTRATIONS: Pers. Obs. Myc. **2**: *pl. 4, f. 2, 3;* Overs. Danske Vid. Selsk. Forh. **1866**: *pl. 3–4;* E. & P. Nat. Pflanzenfam. **1**^{1}**: *f. 33, A, B;* Grev. Crypt. Fl. **3**: *pl. 180;* Bot. Gaz. **49**: *pl. 22, f. 14.*

EXSICCATI: Ellis, N. Am. Fungi *1089;* Seym. & Earle, Econ. Fungi *248x;* Thüm. Myc. Univ. *1325;* Thüm. Fungi Austr. *954;* Sydow, Ured. *242, 840;* West. & Wall, Herb. Crypt. *742;* Sacc. Myc. Ven. *400;* Sacc. Myc. Ital. *45;* Linhart, Fungi Hung. *39, 238;* Sydow. Myc. Mar. *140, 428;* Krieger, Fungi Sax. *319;* Briosi & Cavara, Funghi Paras. *62;* Roum. Fungi Gall. *52;* Cooke, Fungi Brit. *1;* Rab. Fungi Eur. *2196;* Schm. & Kunze, Deutsch. Schwämne *110.*

11. GYMNOSPORANGIUM TORMINALI-JUNIPERINUM Ed. Fisch. Zeits. f. Bot. **2**: 759. 1910

Aecia hypophyllous, in small groups or sometimes solitary, on hypertrophied discolored spots, cylindric, 0.3–0.4 mm. in diameter by 2–3 mm. or more high; peridium finally dehiscent at apex, becoming more or less split along the sides; peridial cells usually seen in side view, rhomboid, 23–29 × 65–90μ, outer wall 2–3μ

thick, smooth, inner and side walls 6–7μ thick, rather finely and very densely rugose with papillae of varying length; aeciospores broadly ellipsoid, 18–23 × 24–27μ, wall light cinnamon-brown, 2–2.5 μ thick, finely verrucose.

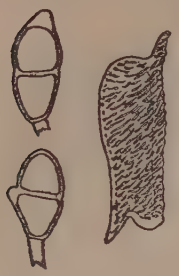


Fig. 12. *G. Torminali-juniperinum.*

Telia chiefly epiphyllous, hemispheric, 0.5–1 mm. or more high, oval or oblong, 1–2 mm. long, dark chestnut-brown, ruptured epidermis conspicuous; teliospores 2-celled, broadly ellipsoid in general outline, 21–30 × 35–49 μ, rounded or sometimes narrowed both above and below, considerably enlarged in one or two places near the septum on one or both cells owing to the presence of hyaline papillae over the germ-pores, wall cinnamon-brown, about 1.5μ thick, papillae 3–6μ; pores 1 or 2 in each cell, apical or near the septum.

Host plants:

For the aecia: *Sorbus latifolia* Pers. (*S. Aria* × *torminalis*), *S. tormimalis* Crantz.

For the telia: *Juniperus communis* L. [*J. sibirica* Burgsd.].

Type locality: Genf (Geneva), Switzerland, on *Juniperus communis.*

Distribution: Europe.

Illustration: Forst. Nat. Zeits. **4**: 348, *f. 4–13.*

Exsiccati: Eriks. Funghi Paras. Scand. *475;* Sydow, Ured. *1230;* Maire & Marg. Exsic. Hypod. Gall. Orient. *26;* Briosi & Cavara, Funghi Paras. *357;* Sydow, Myc. Mar. *4742;* Allesch. & Schn. Fungi Bavar. *216;* Roum. Fungi Gall. *2731.*

12. Gymnosporangium Davisii Kern, Bull. Torrey Club **35**: 507. 1908

Aecia hypophyllous, in irregular or rarely annular groups 1–4 mm. across, on thickened discolored spots, cylindric, acute at apex, 1.5–3 mm. high by 0.4–0.6 m. in diameter; peridium very tardily dehiscent at apex, finally becoming lacerate along the sides; peridial cells seen in both face and side views, broadly lanceolate in face view, 19–26 × 67–87μ, rhomboid in side view, 22–32 thick, outer wall 1.5–2μ thick, smooth, inner and side walls 5–8μ thick, densely rugose with closely set ridge-like papillae of vari-

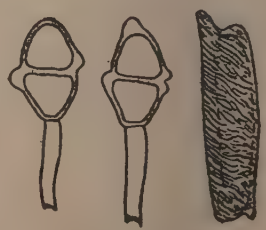


Fig. 13. *G. Davisii.*

able length; aeciospores globoid, 19–25 × 23–27μ, wall dark cinnamon-brown, 1.5–2μ thick, rather finely verrucose.

Telia chiefly epiphyllous, occasionally on the small stems at the bases of the leaves, hemispheric, 0.5–1 mm. high, oval or oblong, 0.7–1 mm. broad by 1–2 mm. long, light chocolate-brown, ruptured epidermis conspicuous; teliospores 2-celled, broadly ellipsoid in general outline, 18–28 × 40–55μ, usually narrowed below, often attenuated at apex and sometimes considerably enlarged near the septum in one or two places on one or both cells owing to the presence of hyaline papillae over the germ-pores, wall cinnamon-brown, 1–1.5μ thick, papillae 4–7μ; pores 1 or 2 in each cell, apical or near the septum.

Host plants:

For the aecia: *Aronia arbutifolia* (L.) Ell., *A. atropurpurea* Britton, *A. nigra* (Willd.) Koehne.

For the telia: *Juniperus sibirica* Burgsd. (*J. nana* Willd.).

Type locality: Wind Lake, Racine Co., Wisconsin, on *Juniperus sibirica.*

Distribution: From Maine west to Michigan and Wisconsin.

13. Gymnosporangium Cunninghamianum Barcl. Sci. Mem. Med. Off. India **5**: 78. 1890

Tremella Cunninghamiana Arth. Proc. Ind.Acad. Sci. **1900**: 136. 1901.

Aecia hypophyllous, often in annular groups of rather large size, 6–16 mm. across, at first cylindric, 0.1–0.3 mm. in diameter, 1–2 mm. high; peridium splitting rather early, becoming deeply fimbriate; peridial cells usually seen in face view, lanceolate, 22–26 by 70–160μ, rhomboid in side view, 19–26μ thick, outer wall rather thin, about 1.5μ, inner and side walls rather thick 5–7μ, coarsely rugose with prominent ridge-like papillae; aeciospores broadly ellipsoid, 25–27 by 28–33μ, wall light chestnut-brown, 1.5–2μ thick, finely verrucose.

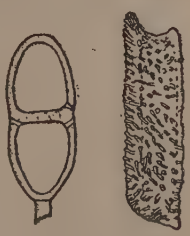


Fig. 14. *G. Cunninghamianum.*

Telia caulicolous, with little or no hypertrophy, appearing on the smaller branches only, hemispheric or slightly tongue-shaped, 1–1.5 mm. across, chestnut-brown; teliospores 2-celled, ellipsoid, 25–30 by 56–72μ, slightly or not constricted, usually rounded above and below, wall cinnamon-brown, rather thick, 3–4μ, pores 1–2 in each cell, near the septum.

Host plants:

For the aecia: *Pyrus variolosa* Wall. (*P. Pashia* D. Don).

For the telia: *Cupressus torulosa* Don.

TYPE LOCALITY: Himalaya Mts., India, on *Cupressus torulosa.*

DISTRIBUTION: Known only from the type locality.

ILLUSTRATION: Sci. Mem. Med. Off. India 5[4]: *pls. 1, 2, 3.*

14. **Gymnosporangium juvenescens** sp. nov.

Aecia chiefly hypophyllous, usually in annular groups 1–2 mm. across, cylindric, 2–4 mm. high by 0.3–0.4 mm. in diameter; peridium tardily dehiscent at apex, first rupturing by longitudinal slits along the sides; peridial cells seen in both face and side views, lanceolate-oblong in face view, 16–23 × 65–110μ, linear-rhomboid in side view, 17–27μ thick, outer wall rather thin, 1–1.5μ, smooth, inner and side walls medium thick, 5–7μ, finely and closely verrucose-rugose with irregular and oftentimes ridge-like papillae; aeciospores globoid, 18–26×21–30μ, wall chestnut-brown, 2–3μ thick, finely verrucose.

Telia caulicolous, often causing a fasciation of the young shoots and forming witches' brooms, usually causing the leaves of the affected branches to take on the subulate juvenile form, apparently arising from the axils of the leaves, hemispheric, 1–2 mm. across by 1–1.5 mm. high, cinnamon-brown; teliospores 2-celled, ellipsoid, 18–26×39–52μ, slightly or not constricted at the septum, usually rounded both above and below, wall pale cinnamon-brown, 1–2μ thick, occasionally slightly thickened over the germ-pores; pores 2 in each cell near the septum, or often only one in the upper cell and apical.

HOST PLANTS:

For the aecia: *Amelanchier alnifolia* Nutt., *A. florida* Lindl., *A. oreophila* Nels., *A. polycarpa* Greene, *A. pumila* Nutt.

For the telia: *Juniperus scopulorum* Sarg. (*Sabina scopulorum* Rydb.), *J. virginiana* L. (*S. virginiana* Antoine).

TYPE LOCALITY: Type collected at Boulder, Colorado, on *Juniperus scopulorum*, April 27, 1907, *Arthur, Bethel & Kern.*

DISTRIBUTION: From British Columbia and Alberta southeast to the Black Hills of South Dakota and to Colorado, and locally in Nebraska and Wisconsin.

ILLUSTRATION: Mycologia **3**: 158, *f. 1c, pl. 48, f. 3.*

EXSICCATI: Ellis & Ev. N. Am. Fungi *3146;* Griff. W. Am. Fungi *246, 264;* Ellis & Ev. Fungi Columb. *1676;* Barth. Fungi Columb. *2527, 2580, 2977;* Vesterg. Micr. Rar. Sel. *1189;* Barth. N. Am. Ured. *108.*

The species here described under a new name is the one which the writer has been referring to in his publications as *G. Nelsoni* but

recent studies, supplemented by cultures, have shown the incorrectness of this interpretation. This species nearly always produces a fasciation of the branch system, forming witches' brooms, and usually causes the leaves of the affected parts to take on the subulate juvenile form. The real *G. Nelsoni* of Arthur does not produce such distortions but appears on gall-like enlargements and appears without doubt to be identical with the writer's *G. durum*. There are also other differences in the character of the telia and teliospores. Both species have aecia on *Amelanchier*, which resemble each other very much in gross appearance, and this fact has been partially responsible for the confusion.

15. Gymnosporangium Kernianum Bethel, Mycologia 3: 157. 1911

Aecia unknown. (Cultures are now in progress but as this paper goes to press no aecia have yet developed.)

Telia caulicolous, arising between the scale-like leaves on the green twigs, causing a fasciation of the young shoots and forming globose witches' brooms 5–60 cm. in diameter, not causing a reversion to the juvenile form, scattered, usually solitary, hemispheric, 0.5–0.8 mm. across, rather compact, dark reddish-brown; teliospores chiefly 2-celled, narrowly ellipsoid, 21–26×55–74μ, narrowed or sometimes rounded at both ends, slightly or not constricted at the septum, wall thin, about 1μ, yellowish; pedicel cylindric; pores usually 2 in each cell, near the septum.

Host plants:

For the aecia: *Amelanchier* spp.

For the telia: *Juniperus utahensis* (Engelm.) Lemm. (*Sabina utahensis* Rydb.).

Type locality: Paonia, Colorado, on *Juniperus utahensis*.

Distribution: Known only from western Colorado.

Illustrations: Mycologia 3: 158, *f. 1a*, *pl. 48*, *f. 2*.

In the small size of the telia and in their manner of arising between the scale-like leaves, this species has a superficial resemblance to *G. inconspicuum* and *G. multiporum* but differs from them in causing witches' broom distortions of the branch-system as well as in several pronounced microscopic characters. It differs from *G. inconspicuum* in having a cylindric instead of carotiform pedicel, from both *G. inconspicuum* and *G. multiporum* in the number and arrangement of the germ-pores, and from *G. multiporum* also in the size and shape of the teliospores. In its tendency to pro-

duce witches' brooms it resembles *G. juvenescens* but differs from that species in the smaller size and different origin of the sori and especially in the greater size of the teliospores.

16. Gymnosporangium trachysorum Kern, Mycologia 2: 237. 1910

Aecia hypophyllous, gregarious, in irregular groups 2–5 mm. across, on discolored slightly thickened spots, cylindric, 2–4 mm. high, 0.2–0.3 mm. in diameter; peridium remaining horn-like, finally rupturing by longitudinal slits along the sides; peridial cells long and narrow in side view, 15–19×32–90μ, lanceolate in face view, 19–23μ broad, outer wall thin, 1.5–2μ, smooth or nearly so, inner and side walls moderately thick, 3–6μ, closely subspinulose with short spine-like papillae interspersed with lower oval or ridge-like papillae; aeciospores globoid or ellipsoid, 15–23 by 18–27μ, wall chestnut-brown, 2.5–3μ thick, minutely verrucose.

Fig. 15. *G. trachysorum.*

Telia caulicolous, appearing on abruptly fusiform or somewhat gall-like enlargements 0.5–1.5 cm. in diameter by 0.5–3 cm. long, unevenly disposed, sometimes closely aggregated, often separated by the scars of the sori of previous seasons, more or less wedge-shaped, often irregular and somewhat lacunose, 1.5–2 mm. broad by 2–4 mm. long at base by 6–10 mm. high, surface rough with irregular warts and ridges, dark chestnut-brown; teliospores 2-celled, ellipsoid, 18–21×37–45μ, wall cinnamon-brown, rather thin, 1.5–2.5μ; pores 1 or 2 in each cell near the septum.

Host plants:

For the aecia: *Crataegus Marshallii* Eggl. (*C. apiifolia* Michx.), *C. flavo-carius* Ashe, *C. Phaenopyrum* (L. f.) Medic. (*C. cordata* Ait.).

For the telia: *Juniperus virginiana* L. (*Sabina virginiana* Antoine).

Type locality: Santee Canal, South Carolina, on *Juniperus virginiana.*

Distribution: From North Carolina southwest to Mississippi and Louisiana.

17. **Gymnosporangium solenoides** (Diet.)

Roestelia solitaria Miyabe, Bot. Mag. Tokyo **17**[2]: 35, hyponym. 1903.

Roestelia solenoides Diet. Bot. Jahrb. **32**: 631. 1903.

Gymnosporangium Miyabei Yamada & Miyake Bot. Mag. Tokyo **22**[1]: 23. 1908.

Aecia hypophyllous, solitary or sometimes several in a group, borne in elongated protuberances of a gall-like nature, 0.2–0.3 mm. in diameter, 2–3 mm. high; peridium dehiscent at apex, not becoming much lacerate; peridial cells usually seen in both face and side views, rhombic or rhomboid in side view, very thick, 42–55μ thick by 65–90μ long, outer wall moderately thin 3–5μ, smooth, inner wall thick, 7–13μ, moderately and densely verrucose with small oval or slightly irregular papillae, side walls verrucose similarly to inner wall on inner half, remainder smooth; aeciospores globoid, 18–24μ in diameter, wall cinnamon-brown, thin, 1–1.5μ, finely verrucose.

FIG. 16. *G. solenoides.*

Telia caulicolous, appearing on irregular fusiform enlargements with a knotty rough surface, at first covered by the periderm, soon breaking forth, pulvinate or somewhat wart-shaped, often confluent, 2–3 mm. across, often much longer, reddish-brown; teliospores 2–3-celled, narrowly ellipsoid, 11–20 by 41–80μ, rounded or slightly narrowed at both ends, wall medium thin, brownish; pores usually 1 in a cell and apical, sometimes near the septum in the upper cell and near the pedicel in the lower.

HOST PLANTS:

For the aecia: *Sorbus Aria* Crantz (*Pyrus aria* Ehrh.), *Sorbus alnifolia* K. Koch (*Pyrus Miyabei* Sarg.).

For the telia: *Chamaecyparis pisifera* Sieb. & Zucc.

TYPE LOCALITY: Prov. Iwaki, Japan, on *Pyrus Aria* (var. *Kamaonensis*).

DISTRIBUTION: Japan.

ILLUSTRATION: Bot. Mag. **22**: *f. 1–9.*

18. **Gymnosporangium tubulatum** comb. nov.

Roestelia tubulata Kern; Jones, Univ. Mont. Bull. **61**: 64. 1910.

Aecia chiefly hypophyllous, crowded in irregular groups on thickened discolored spots, cylindric, acutish at apex, 2–3.5 mm. high by 0.2–0.4 mm. in diameter; peridium firm, tardily dehiscent by longitudinal slits in the lower part; peridial cells fusiform-oblong in face view, 18–26×48–80μ, oblong in side view, 16–24μ thick, outer wall rather thin, 1–1.5μ, smooth, inner and side walls rather thick, 5–6μ, densely and moderately rugose with ridges of varying length; aeciospores globoid or broadly ellipsoid, 18–22×21–28μ, wall light chestnut-brown, 1.5–2.5μ thick, finely verrucose.

Telia unknown.

HOST PLANTS:

For the aecia: *Crataegus Douglasii* Lindl. (*C. brevispina* Dougl.), *C. Williamsii* Eggl.

For the telia: unknown.

TYPE LOCALITY: Near Flathead Lake, Montana, on *Crataegus Douglasii*.

DISTRIBUTION: Known only from western Montana.

19. GYMNOSPORANGIUM BOTRYAPITES (Schw.) Kern, Bull. Torrey Club **35**: 506. 1908

Caeoma (*Roestelia*) *Botryapites* Schw. Trans. Am. Phil. Soc. II. **4**: 294. 1832.

Ceratites (*Caeoma*) *Botryapites* Schw. Trans. Am. Phil. Soc. II. **4**: 310. 1832.

Gymnosporangium biseptatum Ellis, Bull. Torrey Club **5**: 46. 1874.

Roestelia Ellisii Peck, Bull. Torrey Club **6**: 13. 1875.

Roestelia Botryapites Cooke & Ellis, Grev. **5**: 34. 1876.

Puccinia Botryapites Kuntze, Rev. Gen. Pl. **3**: 508. 1898.

Tremella Botryapites Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Aecia hypophyllous, usually in groups of 2–8, rarely solitary, borne in gall-like pyriform protuberances 1–1.5 mm. in diameter by 1.5–3 mm. high, cylindric, 0.5–0.8 mm. in diameter by 2–4 mm. high; peridium soon becoming finely cancellate, not dehiscent at apex; peridial cells cylindric, hyphal-like, 9–14μ in diameter by 145–190μ long, often irregularly bent, outer, inner, and side walls of equal thickness, about 1.5–2μ, whole surface smooth; aeciospores globoid, small, 15–17×16–22μ, wall dark cinnamon-brown, rather thick, 2.5–3μ, moderately verrucose.

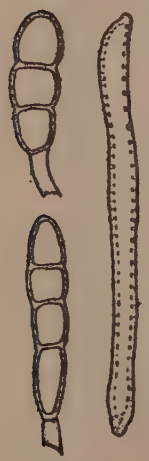


FIG. 17. *G. Botryapites*.

Telia caulicolous, appearing on fusiform swellings, scattered, oval or irregular, about 1.5–3 mm. wide by 2–7 mm. long, often confluent, hemispheric, chestnut-brown; teliospores 2–4 celled, 13–19×35–77μ, usually rounded above, somewhat narrowed below, slightly constricted at the septa, wall pale yellow, 1–1.5μ thick, pores 2 in each cell, near the septa.

HOST PLANTS:

For the aecia: *Amelanchier canadensis* (L.) Medic. (*Amelanchier Botryapium* DC.), *A. intermedia* Spach.

For the telia: *Chamaecyparis thyoides* (L.) B.S.P. (*Chamaecyparis sphaeroidea* Spach, *Cupressus thyoides* L.).

Type locality: Bethlehem, Pennsylvania, on *Aronia Botryapium* [= *Amelanchier canadensis*].

Distribution: Along the Atlantic coast from Massachsetts to New Jersey and Pennsylvania and in southern Alabama.

Illustrations: Hedwigia **34**: 3, *f. 10;* Farlow, Anniv. Mem. Boston. Soc. Nat. Hist. *pl. 2, f. 18–21;* Bot Gaz. **49**: *pl. 22, f. 12.*

Exsiccati: Seym. & Earle, Econ. Fungi *243, 245;* Rab.-Wint. Fungi. Eur. *2922;* Ellis & Ev. Fungi Columb. *1075;* Ellis, N. Am. Fungi *272; 1087;* Thüm. Myc. Univ. *431;* Roum. Fungi Sel. *4534.*

20. Gymnosporangium Nidus-avis Thaxt. Bull. Conn. Exper. Sta. 107: 3. 1891

Roestelia Nidus-avis Thaxt. Bull. Conn. Exper. Sta. 107: 5. 1891.
Puccinia Nidus-avis Kuntze, Rev. Gen. Pl. **3**: 507. 1898.
Tremella Nidus-avis Arth. Proc. Ind. Acad. Sci. **1900**: 136. 1901.
Aecidium Nidus-avis Farlow, Bibl. Index **1**: 68. 1905.

Aecia amphigenous, especially fruiticolous, cylindric, 2–4 mm. high by 0.4–6.7 mm. in diameter; peridium soon becoming irregularly lacerate usually to base, slightly spreading; peridial cells seen in both face and side views, lanceolate in face view, 15–23×55–88μ, linear in side view, 14–18 μ thick, outer wall 1–1.5μ thick, smooth, inner and side walls 5–7μ thick, coarsely rugose with narrow ridges, with shorter often roundish papillae interspersed; aeciospores globoid or broadly ellipsoid, 18–23×23–28μ, wall cinnamon-brown, rather thick, 2.5–4μ, very finely verrucose, appearing almost smooth when wet.

Fig. 18. *G. Nidus-avis.*

Telia caulicolous, often dwarfing the young shoots and causing bird's nest distortions or witches' brooms, usually causing a reversion of the leaves to the juvenile form, sometimes appearing on isolated areas on the larger branches and producing gradual enlargements, solitary or rarely confluent, of variable size and shape, roundish to oval on the young shoots, 1–2 mm. across, oval to narrowly elliptic on the woody branches, 1.5–3 mm. wide by 2–7 mm. long, pulvinate when young becoming hemispheric, dark reddish-brown; teliospores 2-celled, ellipsoid, 16–23×39–55μ, wall pale cinnamon-brown, rather thin, 1–1.5μ, very slightly thicker at apex; pores one in a cell, apical.

HOST PLANTS:

For the aecia: *Amelanchier canadensis* (L.) Medic., *A. erecta* Blanch., *A. intermedia* Spach., *A. oblongifolia* (Torr. & Gray) Roem., *A. vulgaris* Moench (cult.), *Cydonia vulgaris* (L.) Pers.

For the telia: *Juniperus virginiana* L.

TYPE LOCALITY: Connecticut, on *Juniperus virginiana.*

DISTRIBUTION: Massachusetts west to Wisconsin and Iowa, south to Florida and Mississippi.

ILLUSTRATION: Bot. Gaz. **49**: *pl. 22, f. 10.*

EXSICCATI: Rab.-Wint. Fungi Eur. *2923;* Ellis, N. Am. Fungi *1083b, 1086c;* Seym. & Earle, Econ. Fungi *239, 240;* Ellis & Ev. Fungi Columb. *1623;* Ellis & Ev. N. Am. Fungi *3145;* Rav. Fungi Am. *791;* Kellerm. Ohio Fungi *185;* Rav. Fungi Carol. **5**: *87.*

21. GYMNOSPORANGIUM EXTERUM Arth. & Kern; Arth. Mycologia **1**: 254. 1909

Aecia hypophyllous, very sparsely disposed in large groups 4–10 mm. across, on discolored spots, 0.1–0.3 mm. in diameter by 0.5–0.8 mm. high; peridium soon becoming rather finely lacerate almost to base, spreading but not revolute; peridial cells usually seen only in face view, lanceolate, 10–18×58–100μ, inner wall rugose with narrow ridges, side walls 3–5μ thick, sculptured over whole surface like inner wall; aeciospores broadly ellipsoid or globoid, 17–21×21–26μ, wall very pale cinnamon-brown, 2–2.5μ thick, very finely verrucose.

Telia caulicolous, appearing on fusiform dwellings 2–6 cm. long by 0.5–1.5 cm. or more in diameter, causing a considerable roughening and exfoliation of the bark, flattened and applanate, irregular and indefinite in outline, usually anastomosing over practically the whole surface of a swelling, light chocolate-brown; teliospores 2-celled, 18–23 ×32–42μ, very slightly or not at all constricted at the septum, wall light cinnamon-brown, rather thin, 1–1.5μ, usually slightly thicker at apex; pores one in a cell, apical.

HOST PLANTS:

For the aecia: *Porteranthus stipulatus* (Muhl.) Britton (*Gillenia stipulacea* Nutt., *Spiraea stipulata* Muhl.).

For the telia: *Juniperus virginiana* L.

TYPE LOCALITY: Mammoth Cave, Kentucky, on *Juniperus virginiana.*

DISTRIBUTION: Small area from Central Kentucky to southeastern Missouri.

EXSICCATI: Rab.-Wint. Fungi Eur. *3323.*

22. GYMNOSPORANGIUM GERMINALE (Schw.) Kern, Bull. Torrey Club **35**: 506. 1908

Caeoma (*Peridermium*) *germinale* Schw. Trans. Am. Phil. Soc. II. **4**: 294. 1832.

Peridermium (*Caeoma*) *germinale* Schw. Trans. Am. Phil. Soc. II. **4**: 310. 1832.

Podisoma Gymnosporangium clavipes Cooke & Peck, Jour. Quek. Cl. **2**: 267. 1871.

Gymnosporangium clavipes Cooke & Peck, Ann. Rep. N. Y. State Mus. **25**: 89. 1873.

Roestelia aurantiaca Peck, Ann. Rep. N. Y. State Mus. **25**: 91. 1873.

Puccinia clavipes Kuntze, Rev. Gen. Pl. **3**: 507. 1898.

Tremella clavipes Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Aecidium aurantiacum Farlow, Bibl. Index **1**: 19. 1905. Not *A. aurantiacum* Bon. 1860.

Aecidium germinale Arth. Résult. Sci. Congr. Bot. Vienne 343. 1906.

Aecia fruiticolous and caulicolous, crowded on hypertrophied areas of variable size on the twigs and peduncles, occupying part or nearly all of the surface of the fruits, cylindric, 1.5–3 mm. high by 0.3–0.5 mm. in diameter; peridium whitish, becoming coarsely laceate, sometimes to base, erect or spreading; peridial cells seen in both face and side views, polygonal-ovate or polygonal oblong in face view, 19–39×45–95μ, rhomboid in side view, 25–40μ thick, outer wall moderately thick, 3–5μ, inner wall very thick, 13–23μ,coarsely verrucose with loosely set, large, irregularly branched papillae, side walls verrucose on inner half similar to inner wall; aeciospores globoid, large, 21–32×24–39μ, wall pale yellow, thick, 3–4.5μ, rather coarsely verrucose with crowded slightly irregular papillae.

FIG. 19. *G. germinale*

Telia caulicolous, appearing on slight fusiform swellings, usually aggregated, roundish, 1–4 mm. across, often confluent, hemispheric, 1–3 mm. high, orange-brown; teliospores 2-celled, ellipsoid, 18–26×35–51μ, roundish or somewhat acutish above, obtuse below, slightly or not constricted at the septum, wall yellowish, 1–2μ thick, slightly thicker at the apex; pedicels carotiform, 9–19μ in diameter near the spore; pores one in each cell, apical in the upper, near the pedicel in the lower.

HOST PLANTS:

For the aecia: *Amelanchier canadensis* (L.) Medic., *A. erecta* Blanch., *A. intermedia* Spach., *A. oligocarpa* (Michx.) Roem., *A. oblongifolia* (Torr. & Gray) Roem., *A. rotundifolia* (Michx.) Roem., *Aronia arbutifolia* (L.) Ell., *A. atropurpurea* Britton, *A. nigra* (Willd.) Britton, *A. monstrosa* Zabel (*A. arbutifolia*×*Sorbus americana*), *Crataegus colonica* Beadle, *C. crus-galli* L., *C. dispar* Beadle, *C. flava* Ait., *C. Jonesae* Sarg., *C. mollis* (Torr. & Gray) Scheele, *C. punctata* Jacq., *C. Reverchoni* Sarg., *C. rotundifolia* Moench, *C. spatulata* Michx., *Cydonia vulgaris* (L.) Pers., *C. japonica* (Thunb.) Pers. (*Chaenomeles japonica* Lindl.), *Malus Malus* (L.) Britton (*Pyrus Malus* L.).

For the telia: *Juniperus communis* L., *J. sibirica* Burgsd. (*J. nana* Willd.), *J. virginiana* L.

TYPE LOCALITY: Philadelphia, Pennsylvania, "in germinibus Rosae," error for *Crataegus*.

DISTRIBUTION: From Maine west to northern peninsula of Michigan and Iowa, south to northern Florida and Texas.

ILLUSTRATIONS: Hedwigia **34**: 3, *f. 7;* Bot. Gaz. **49**: *pl. 21, f. 9.*

EXSICCATI: Seym. & Earle, Econ. Fungi *234, 235, 236, 237, 238;* Rav. Fungi Am. *271, 272, 502;* Ellis, N. Am. Fungi *1083a, 1084;* Ellis & Ev. N. Am. Fungi *2224;* Ellis & Ev. Fungi Columb. *54, 1732;* Thüm. Myc. Univ. *44*; Kellerm. Ohio Fungi *21.*

23. GYMNOSPORANGIUM JUNIPERINUM (L.) Mart. Fl. Crypt. Erlang. 333. 1817

Tremella juniperina L. Sp. Pl. 1157. 1753.
Aecidium penicillatum Pers. in J. F. Gmel. Syst. Nat. **2**: 1472. 1791.
Caeoma penicillatum Schlecht. Fl. Berol. **2**: 111. 1824.
Centridium Ariae Desm. Pl. Crypt. *1378.* 1845.
Roestelia penicillata Fries, Sum. Veg. Scand. **2**: 510. 1849.
Ceratitium penicillatum Rabenh. Bot. Zeit. **9**: 452. 1851.
?*Podisoma Gymnosporangium* Bon. Handb. 148. 1851.
Podisoma tremelloides A. Braun, Bot. Zeit. **25**: 94. 1867.
Gymnosporangium tremelloides R. Hartig, Lehr. Baumkr. **1**: 333. 1882.
Puccinia juniperina Kuntze, Rev. Gen. Pl. **3**: 507. 1898.
Tremella penicillata Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Roestelia fimbriata Arth. Bull. Torrey Club **28**: 666. 1901.
Aecidium fimbriatum Farlow, Bibl. Index **1**: 44. 1905.
Gymnosporangium penicillatum Liro, Ured. Fenn. 405. 1908.

Aecia hypophyllous, in annular or crowded groups, 2–5 mm. across, on larger thickened discolored spots, at first cylindric, 0.5–1.5 mm. high, 0.5–1 mm. in diameter; peridium soon becoming finely fimbriate to base and somewhat twisted or incurved; peridial cells usually seen only in side view, rhomboid, very thick, 30–35 × 60–90 μ, outer wall medium thin, 2–3 μ, smooth, inner wall medium thick, 7–10 μ, rugose, side walls very coarsely rugose with thick, somewhat irregular ridges, roundish or elongate ridge-like papillae interspersed; aeciospores globoid, very large, 28–35 × 30–45 μ, wall chestnut-brown, thick, 3–5 μ, rather finely verrucose.

Fig. 20. *G. juniperinum.*

Telia caulicolous, appearing on hemispheric swellings (1–4 cm. long) breaking forth along the sides of the larger branches, or on subglobose galls (1.5–2 cm. in diameter) on the smaller branches, applanate, indefinite, usually of considerable size, often covering the whole hypertrophied area, sometimes becoming patelliform when expanded, chocolate-brown; teliospores 2-celled, ellipsoid 18–28 × 42–61 μ, usually slightly narrowed both above and below, slightly or not constricted at the septum, wall cinnamon-brown, 1–1.5 μ thick; pores usually 3 in the upper cell, 1 apical, 2 near the septum, in the lower cell 2 near the septum.

Host plants:

For the aecia: *Malus Malus* (L.) Britton (*Pyrus Malus* L.) (in Europe only), *Sorbus Aria* Crantz, *S. Chaemaemespilus* Crantz, *S. Hostii* Koch (*S. Aria* × *Chaemaemespilus*), *S. hybrida* L. (*S. Aria* × *aucuparia*), *S. latifolia* Pers. (*S. Aria* × *torminalis*), *S. occidentalis* (Wats.) Greene, *S. scopulina* Greene, *S. sitchensis* Roem.

For the telia: *Juniperus communis* L., *J. sibirica* Burgsd. (*J. nana* Willd.).

Type locality: Sweden, on *Juniperus* [*communis*].

Distribution: Rocky Mountains from Alberta and British Columbia south to Colorado; and in Europe.

Illustrations: Beitr. Krypt. Schweiz. **2**[2]: *f. 277;* Hedwigia **34**: 3, *f. 1;* Bot. Gaz. **49**: *pl. 21, f. 8;* E. & P. Nat. Pflanzenfam. **1**[1**]: *f. 33, C, D, E;* Forst. Nat. Zeits. **4**: 348, *f. 1–3, 14–16.*

Exsiccati: Briosi & Cavara, Funghi Paras. *161, 163;* Sydow, Ured. *380, 585, 799, 1288, 1289, 1885;* Linhart, Fungi Hung. *39, 132, 245;* Roum. Fungi Sel. *7339;* Sacc. Myc. Ital. *457, 921, 1096;* Sacc. Myc. Venet. *398;* Sydow, Myc. Mar. *1816;* Eriks. Fungi Par. Scand. *75, 180;* Rab. Fungi Eur. *1390;* Rab.-Wint.-Paz. Fungi Eur. *4015;* Rab. Herb. Mycol. *788;* Desm. Pl. Crypt. *1378;* Thüm. Myc. Univ. *745, 1122;* West. & Wall. Herb. Crypt. *1064.*

Although the writer has previously given brief statements (Kern, 1908[1], 1908[2]) of his disposition of the specific name *juniperinum* a further explanation seems desirable. It seems clear from the literature that Linnaeus and the writers who followed him for a hundred years or more used this name to refer to a large conspicuous form such as is known to belong with *Roestelia penicillata.* Oersted (1866[1]) is responsible for introducing the use of the name *juniperinum* for the smaller and less conspicuous form which he culturally connected with *Roestelia cornuta.* European writers since the time of Oersted have been uncertain in the use of this name. Recently Fischer (1909, 1910) has shown by cultures that at least three distinct species have quite generally been included by most European authors under this name. He separates out under the name *G. Amelanchieris,* a small twig-inhabiting form belonging with an aecial form on *Amelanchier,* and under the name *G. Torminali-juniperinum* an inconspicuous leaf-inhabiting form producing its aecial phase on *Sorbus torminalis.* By a sort of process of elimination he retains the name *juniperinum* for the form related to *Roestelia cornuta* on *Sorbus Aucuparia.* In this, Fischer follows Oersted but since the evidence indicates he was originally responsible for a misuse of the name the writer hesitates to accept this interpretation. The disposition of the name *juniperinum,* previously suggested by the writer and here retained, appears to be in accordance with the prior conception.

24. **Gymnosporangium gracilens** (Peck) Kern & Bethel.

Aecidium gracilens Peck, Bot. Gaz. **4**: 128. 1879.
Gymnosporangium speciosum Peck, Bot. Gaz. **4**: 217. 1879.
Aecidium Rusbyi Gerard, Bull. Torrey Club. 8: 34. 1881.
Tremella speciosa Arth. Proc. Ind. Acad. Sci. **1900**: 35. 1901.

Aecia hypophyllous, in small groups 2–5 mm. across, on discolored spots, cylindric, 0.3–0.4 mm. in diameter by 2–3 mm. high; peri-

dium dehiscent at apex, retaining tubular form, margin rather deeply lacerate; peridial cells seen in both face and side views, rhomboid or linear-rhomboid in side view, 31–39×71–98μ, broadly lanceolate in face view, 23–32μ broad, moderately and densely verrucose over entire surface with high, slender, and somewhat irregular papillæ, outer wall 3–4μ thick, inner wall 10–15μ thick; aeciospores subgloboid, 21–24×24–29μ, wall pale yellow, 2.5–3.5μ thick, finely verrucose.

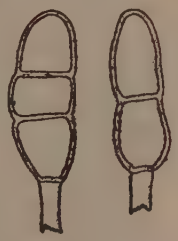


FIG. 21. *G. gracilens.*

Telia caulicolous, appearing on long fusiform swellings, arranged in more or less evident longitudinal rows, cristiform, laterally compressed, irregularly crenate above, 2–7 mm. long, 1–1.5 mm. broad, 3–4 mm. high, sometimes confluent, orange yellow; teliospores 2–3-celled, ellipsoid or oblong, 20–26×50–80μ, rounded above and below, slightly constricted at the septa, wall pale yellow, thin, about 1μ; pores 2 in each cell, near the septa.

HOST PLANTS:

For the aecia: *Fendlera rupicola* Engelm. & Gray, *F. Wrightii* Heller, *Philadelphus ellipticus* Rydb., P. *microphyllus* A. Gray, *P. occidentalis* A. Nels.

For the telia: *J. monosperma* (Engelm.) Sarg. (*Sabina monosperma* Rydb.), *J. pachyphlaea* Torr. (*Sabina pachyphlaea* Antoine), *J. utahensis* (Engelm.) Lemm. (*S. utahensis* Rydb.).

TYPE LOCALITY: Colorado, on *Philadelphus microphyllus*.

DISTRIBUTION: Colorado southwest into New Mexico and Arizona.

It has recently been suggested by Bethel (1911) that *Aecidium gracilens* Peck on *Philadelphus spp.* is the probable aecial stage of this species. I am especially glad to be able to report that cultures have since been made which prove the correctness of Professor Bethel's keen observations. This result is unusually noteworthy because *Philadelphus* does not belong to the Malaceae or Rosaceae, the only two families previously known to bear aecia of the heteroecious species of *Gymnosporangium*, but to the Hydrangiaceae.

25. **Gymnosporangium effusum** sp. nov.

Aecia unknown.

Telia caulicolous, usually appearing on branches 0.3–1.5 cm. in diameter, causing long slender fusiform enlargements 0.5–2.5

by 15–40 cm., extending into and causing some swelling of the smaller branches and twigs arising from the infected areas, sometimes appearing on larger branches, usually breaking forth in series along the branch, unevenly disposed, hypertrophied scars of the sori of previous seasons frequently interspersed, somewhat wedge-shaped, often irregular and lacunose, sometimes forked or divided, 2–3 mm. broad by 2–5 mm. long at the base, 7–10 mm. high, dark chestnut-brown; teliospores 2-celled, oblong-ellipsoid, 16–22 by 45–55μ, rounded or slightly narrowed both above and below, slightly constricted at the septum, wall dark cinnamon-brown, rather thin, 1–2μ; pores 1–2 in each cell, near the septum.

Host plants:

For the aecia: unknown.

For the telia: *Juniperus virginiana* L.

Type collected at Santee Canal, S. C., on *Juniperus virginiana*, March 18, 1909, *Frank D. Kern.*

Distribution: Along the Atlantic coast from New York south to South Carolina.

In the generally wedge-shaped telia with their rough and irregular surfaces, especially noticeable when expanded, this species resembles *G. trachysorum* but in the character of the hypertrophies upon which the telia appear the two species are quite distinct. This species is very destructive to the cedars on account of its habit of attacking and spreading along the larger branches.

26. Gymnosporangium japonicum Sydow, Hedwigia Beib. **38**: 141. 1899

Roestelia koreaensis P. Henn. Monsunia **1**: 5. 1900.

Tremella koreaensis Arth. Proc. Ind. Acad. Sci. **1900**: 136. 1901.

Aecia hypophyllous, in crowded or somewhat annular groups, on thickened discolored spots, cylindric, 0.4–0.5 mm. in diameter by 2–3 mm. high; peridium soon becoming irregularly lacerate and cancellate often to base, erect or slightly spreading; peridial cells seen in both face and side views, broadly lanceolate or oval in face view, 29–32 by 64–90μ, oblong in side view, 23–32μ thick, coarsely rugose on inner and side walls, the ridges becoming much higher on side walls and extending clear across, outer wall 1.5–2μ thick, inner and side walls 5–7μ; aeciospores globoid, 18–21 by 19–23μ, wall pale cinnamon-brown, medium, 1.5–2μ thick, very finely verrucose.

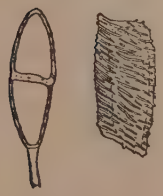


Fig. 22. *G. japonicum.*

Telia caulicolous, appearing on gradual fusiform enlargements,

scattered, irregularly wedge-shaped, often incised at apex and lacunose below, 3–5 mm. high, cinnamon-brown; teliospores 2-celled, ellipsoid, 18–22 by 57–66μ, not or very slightly constricted, usually narrowed above and below, wall pale cinnamon-brown, rather thin, 1–1.5μ; pores 2 in each cell, near the septum.

HOST PLANTS:

For the aecia: *Pyrus sp.* (Has been cultivated on *Pyrus sinensis* Lindl.)

For the telia: *Juniperus chinensis* L.

TYPE LOCALITY: Tokyo, Japan, on *Juniperus chinensis.*

DISTRIBUTION: Japan and Korea. (Recently reported in the United States by Clinton on *J. chinensis* imported from Japan.)

ILLUSTRATIONS: Zeits. f. Pflanzenkr. **10**: *pl. 1–2.*

EXSICCATI: Sydow, Ured. *1287.*

27. GYMNOSPORANGIUM SABINAE (Dicks.) Wint. in Rab. Krypt. Fl. 1^1: 232. 1884

Tremella Sabinae Dicks. Pl. Crypt. Brit. **1**: 14. 1785.

Aecidium cancellatum Pers. in J. F. Gmelin, Syst. Nat. 2^2: 1472. 1791.

Roestelia cancellata Rebent. Fl. Neom. 350. 1804.

?Gymnosporangium conicum Hedw. f.; DC. Fl. Fr. **2**: 216. 1805.

Gymnosporangium fuscum Hedw. f.; DC. Fl. Fr. **2**: 217. 1805.

Caeoma Roestelites Link, in Willd. Sp. Pl. 6^2: 64. 1825.

Podisoma Juniperi Link, in Willd. Sp. Pl. 6^2: 127. 1825.

Cyglides calyptratum Chev. Fl. Env. Paris **1**: 384. 1826.

Aecia hypophyllous, gregarious, on thickened discolored spots, large, balaniform, 0.5–1 mm. broad at the base by 1–2 mm. high; peridium soon becoming cancellate along the sides, apex bluntly conic; peridial cells usually seen in side view, rhomboid or linear-rhomboid, 18–23 by 66–98μ, inner and side walls moderately verrucose with roundish or oval papillae; aeciospores globoid, 23–29 by 26–32μ, wall light chestnut-brown, rather thick, 3–4μ, finely verrucose.

FIG. 23. *G. Sabinae.*

Telia caulicolous, causing very slight or no enlargements, conic or laterally compressed, 6–10 mm. or more long, often somewhat lacunose, chestnut-brown; teliospores 2-celled ellipsoid, 19–30 by 37–48μ, usually narrowed at both ends, usually slightly constricted at the septum, wall cinnamon-brown to light chestnut-brown, 2–3μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Pyrus betulifolia* Bunge, *P. communis* L., *P. eleaginifolia* Pall., *P. Michauxii* (hort), *P. nivalis* Jacq., *P. salicifolii* L., *P. tomentosa* Moench.

For the telia: *Juniperus chinensis* L., *J. japonica* Carr., *J. phoenica* L., *J. Sabina* L., *J. sphaerica* Lindl., *J. tripartita* (hort), *J. virginiana* L.

Distribution: Europe.

Illustrations: Beitr. Krypt. Schweiz 2^3: *f. 279;* Hedwigia **34**: 3, *f. 4;* E. & P. Nat. Pflanzenfam. 1^{1**}: *f. 32.*

Exsiccati: Sacc. Myc. Ital. *709;* Sydow, Ured. *86, 87, 88, 379, 1435, 1436;* Sydow, Myc. Mar. *72, 427, 2510, 2746, 2747, 3128, 4126;* Eriks. Fungi Paras. Scand. *279;* Thüm. Myc. Univ. *537, 1435;* Krieger, Schäd. Pilze *14, 15;* Briosi & Cavara, Funghi Parass. *131;* Rab. Fungi Eur. *1882;* Linhart, Fungi Hung. *237;* Allesch. & Schn. Fungi Bavar. *31;* Krieger, Fungi Sax. *60, 477;* Roum. Fungi Gall. *252, 434.*

28. **Gymnosporangium Mespili** (DC.)

Aecidium Mespili DC. Fl. Fr. **6**: 98. 1815.

Aecidium Cydoniae Lenorm.; Duby, Bot. Gall. **2**: 903. 1830.

Aecidium Cotoneasteris Körn. Hedwigia **16**: 24. 1877.

Roestelia Cydoniae Thüm. (Fungi Parenzo *278*) in Sacc. Syll. Fung. **7**: 834. 1888.

Gymnosporangium confusum Plowr. Brit. Ured. et Ustil. 232. 1889.

Tremella Mespili Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Aecia hypophyllous and caulicolous, gregarious, cylindric, slender, 0.1–0.2 mm. in diameter by 1–2 mm. high; peridium soon becoming irregularly lacerate, often nearly to base, somewhat spreading; peridial cells seen in both side and face views, linear-rhomboid in side view, 15–24 by 65–80μ, lanceoate in face view, 17–21μ broad, outer wall thin, 1–1.5μ, smooth, inner and side walls rather thick 5–7μ, rather strongly rugose with ridges of varying length; aeciospores globoid, 19–22 by 19–26μ, wall rather thick, 2.5–3.5μ, cinnamon-brown, finely verrucose.

Fig. 24. *G. Mespili.*

Telia caulicolous causing very slight fusiform enlargements, conic or laterally compressed, 5–8 mm. high, dark chestnut-brown; teliospores 2-celled, ellipsoid, 19–26 by 35–48μ, mostly not constricted at the septum, usually rounded at the apex and narrowed below, wall

cinnamon- to chestnut-brown, 1.5–3μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Cotoneaster tomentosa* Lindl., *C. vulgaris* Lindl., *Cydonia vulgaris* (L.) Pers., *Crataegus orientalis* Lindl., *C. oxyacantha* L., *C. grandiflora* Koch., *C. pinnatifida* Bunge, *C. tanacetifolia* Pers., *C. monogyna* Jacq., *Mespilus germanica* L., *Pyrus communis* L.,

For the telia: *Juniperus Sabina* L., *J. virginiana* L.

Type locality: Brussels, Belgium, on *Mespilus germanica.*

Distribution: Europe and Central Asia.

Illustrations: Beitr. Krypt. Schweiz **2**^{2}: *f. 276;* Hedwigia **34**: 3, *f. 5;* Tubeuf, Pflanzenkr. *f. 207–213.*

Exsiccati: Sydow, Ured. *134, 148, 149, 199, 292, 293, 294, 295, 839, 892, 893, 947, 2046, 2047;* Krieger, Fungi Sax. *361;* Sydow, Myc. Mar. *1429, 1703, 1904, 2648, 2649, 2921, 2922, 3812, 4125, 4229;* Roum. Fungi Gall. *3419, 3863;* Thüm. Myc. Univ. *1429;* Rab. Fungi Eur. *1985;* Briosi & Cavara, Funghi Paras. *288, 319.*

29. **Gymnosporangium transformans** (Ellis)

Roestelia transformans Ellis; Peck. Bull. Torrey Club **5**: 3. 1874.
Aecidium transformans Pazschke, in Rab. Fungi Eur. *4238.* 1901.

Aecia hypophyllous, caulicolous, and fruiticolous, occasionally solitary, usually gregarious, sometimes few together but more often aggregated in large groups, borne in gall-like, frustum-shaped protuberances (1–2 mm. high) of a reddish brown color which are more or less consolidated at the bases when in groups, at first cylindrical, 2–2.5 mm. high by 0.2–0.4 mm. in diameter; peridium soon becoming finely fimbriate to base, partially dropping away, remainder spreading and twisted; peridial cells usually seen only in side view, very long and narrow, becoming curved or even coiled when wet, 12–18μ thick by 150–300μ or more long (shorter toward apex of peridium), outer wall 2–3 μ thick, smooth, inner wall 4–6μ thick, rather coarsely verrucose, side walls verrucose on inner half with roundish or somewhat irregular papillae; aeciospores globose, small, 18–22μ in diameter, wall light cinnamon-brown, 1.5–2.5μ thick, rather finely verrucose.

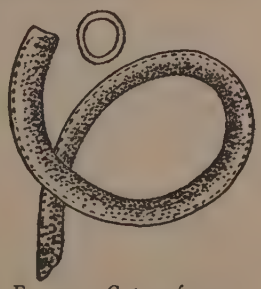


Fig. 25. *G. transformans.*

Telia unknown.

Host plants:

For the aecia: *Aronia arbutifolia* (L. f.) Ell. (*Pyrus arbutifolia* L. f.).

For the telia: unknown.

Type locality: Newfield, N. J., on *Pyrus arbutifolia*.

Distribution: Small area along the Atlantic coast from Massachusetts to New Jersey.

Illustration: Bot. Gaz. **49**: *pl. 21, f. 7*.

Exsiccati: Ellis, N. Am. Fungi *1088;* Seym. & Earle, Econ. Fungi *247, 247a;* Roum. Fungi Sel. *4533;* Thüm. Myc. Univ. *1029;* Rab.-Paz. Fungi Eur. *4238*.

30. Gymnosporangium clavariaeforme (Jacq.) DC. Fl. Fr. **2**: 217. 1805

Tremella clavariaeforme Jacq. Collectan. **2**: 174. 1788.
Tremella ligularis Bull. Herb. Fr. pl. 427. 1788.
Tremella digitata Vill. Hist. Pl. Dauph. **3**: 1007. 1789.
Aecidium laceratum Sow. Engl. Fungi 318. 1801.
Aecidium Oxyacanthae Pers. Syn. Fung. 206. 1801.
Cyglides laceratum Chev. Fl. Env. Paris **1**: 384. 1826.
Podisoma ligulatum Chev. Fl. Env. Paris **1**: 423. 1826.
Tremella juniperina Wahl. Fl. Suec. 994. 1826.
Podisoma clavariaeforme Duby, Bot. Gall. **2**: 881. 1830.
Podisoma Juniperi-communis Fries, Syst. Myc. **3**: 508. 1832.
Roestelia lacerata Fries, Sum. Veg. Scand. **2**: 510. 1849.
Roestelia carpophila Bagnis, Flora **63**: 317. 1880.
Roestelia lacerata x Thaxter, Proc. Amer. Acad. **22**: 266. 1887.
Puccinia penicillata Kuntze, Rev. Gen. Pl. **3**: 508. 1898.
Gymnosporangium gracile Pat. Bull. Soc. Myc. Fr. **18**: 46. 1902.
Gymnosporangium Oxycedri Bres. Broteria **2**: 88. 1903.
Aecidium clavariaeforme Arth. Résult. Sci. Congr. Bot. Vienne 343. 1905.

Aecia hypophyllous, fruiticolous, and caulicolous, usually crowded in small groups 2–3 mm. across on the leaf blades, sometimes in larger groups on the veins, petioles, and twigs, often densely aggregated on the fruits and occupying part or all of the surface, cylindric, 0.7–1.5 mm. high by 0.3–0.5 mm. in diameter; peridium soon becoming lacerate, usually to base, erect or spreading; peridial cells long and narrow, often becoming curved when wet, linear in face view, 18–30×80–130μ, linear or linear-oblong

in side view, 15–25μ thick, outer wall 1–2μ thick, smooth, inner wall and side walls 5–7μ thick, rather coarsely verrucose with roundish or irregular papillae of varying sizes; aeciospores globoid, 21–27×25–30μ, wall light cinnamon-brown, 2.5–3.5μ thick, moderately verrucose.

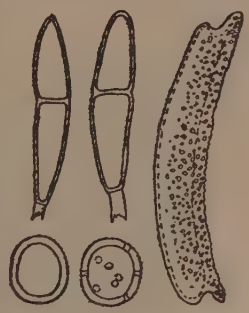


Fig. 26. *G. clavariaeforme.*

Telia caulicolous, appearing on long fusiform swellings of various sized branches, numerous, scattered or sometimes aggregated, cylindric, or slightly compressed, 5–10 mm. long by 0.8–1.5 mm. in diameter, acutish or sometimes forked at the apex, brownish yellow; teliospores 2-celled, lanceolate, 13–20×50–80μ, occasionally longer, rounded or narrowed above, usually narrowed below, very slightly or not at all constricted at the septum, wall golden-yellow, thin, about 1μ; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Amelanchier alnifolia* Nutt., *A. canadensis* (L.) Medic., *A. intermedia* Spach., *A. oblongifolia* (Torr. & Gray) Roem., *A. oreophila* A. Nels., *A. polycarpa* Greene, *A. pumila* Nutt., *Aronia arbutifolia* (L.) Medic. (*Pyrus arbutifolia* L.), *Cotoneaster vulgaris* (L.) Pers., *Crataegus monogyna* Jacq., *C. nigra* Waldsb. & Kit., *C. oxyacantha* L., *C. pyracantha* Pers., *C. tanacetifolia* Pers., *Cydonia vulgaris* (L.) Pers., *Pyrus communis* L.

For the telia: *Juniperus communis* L., *J. oxycedrus* L., *J. sibirica* Burgsd. (*J. nana* Willd.).

Type locality: Corinthia, on *Juniperus communis.*

Distribution: Maine and Delaware west to Wisconsin and northeastern Iowa, and in Wyoming and Colorado; and in Europe.

Illustrations: Beitr. Krypt. Schweiz. **2**^{2}: *f. 275;* Hedwigia **34**: 3, *f. 3;* Grev. Crypt. Fl. **4**: *pl. 209;* Bot. Gaz. **49**:*pl. 21, f. 6.*

Exsiccati: Ellis & Ev. Fungi Columb. *56;* Ellis, N. Am. Fungi *273;* Seym. & Earle, Econ. Fungi *241, 242a, b, c;* Syd. Ured. *134, 1036, 1692;* Sydow. Myc. Mar. *830;* Briosi & Cavara, Funghi Paras. *39;* Krieger, Fungi Sax. *361, 362;* Linhart, Fungi Hung. *332;* Rab. Fungi Eur. *2197;* Sacc. Myc. Ital. *256, 921;* Thüm. Myc. Univ. *1036, 1326;* Cooke, Fungi Brit. *2, 125;* Roum. Fungi Gall. *749, 1263, 2248;* Desm. Pl. Crypt. *1546;* Allesch. & Schn. Fungi Bavar. *32;* Vesterg. Microm. Rar. Sel. *756.*

31. **Gymnosporangium Yamadae** Miyabe (Bot. Mag. Tokyo **17**[2]: 34, hyponym. 1903), sp. nov.

Aecia hypophyllous, in groups 2–3 mm. across on thickened discolored spots, tubular at first, 0.1–0.3 mm. in diam. by 1–3 mm. high; peridium becoming lacerate or fimbriate to base, spreading; peridial cells linear-rhomboid in side view, 18–24×55–95μ, outer wall thin, about 1μ, smooth, inner and side walls medium thin, 3–4μ, moderately verruculose with small, mostly oval papillae; aeciospores broadly ellipsoid or globoid, 17–21 ×21–26μ, wall chestnut-brown, 1.5–2.5μ thick, finely verrucose.

Fig. 27. *G. Yamadae.*

Telia unknown.

Host plants:

For the aecia: *Malus Malus* (L.) Britt. (*Pyrus Malus* L.), *M. spectabilis* (Ait.) Borkh. (*Pyrus spectabilis* Ait.), *M. Toringo* Sieb. (*Pyrus Toringo* Koch.).

For the telia: unknown.

Type collected at Tokyo, Japan, on *Pyrus spectabilis*, June 23, 1904, *N. Nambu.*

Distribution: Known only from type locality.

32. Gymnosporangium Ellisii (Berk.) Farlow, in Ellis, N. Am. Fungi *271.* 1879

Podisoma Ellisii Berk. Grevillea **3**: 56. 1874.
Hamaspora Ellisii Körn. Hedwigia **16**: 23. 1877.
Phragmidium Ellisii De Toni, in Sacc. Syll. Fung. **7**: 750. 1888.
Tremella Ellisii Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Aecia unknown.

Telia caulicolous, from a perennial mycelium which distorts the younger branches causing slight enlargements and usually dense fasciations, numerous, thickly scattered, often over considerable areas, cylindric, filiform, 3–6 mm. long. about 0.5–1 mm. in diameter, orange-colored; teliospores 2–5-celled, linear-fusiform, 9–16×85–170μ, not constricted at the septa, wall pale yellow, thin about 1μ; pores 2 in each cell (1 in the uppermost), apical.

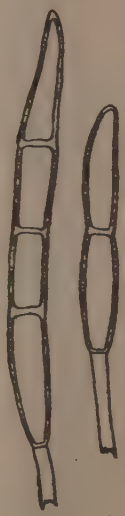


Fig. 28. *G. Ellisii.*

Host plants:

For the aecia: unknown.

For the telia: *Chamaecyparis thyoides* (L.) B.S.P. (*Cupressus thyoides* L., *Chamaecyparis sphaeroidea* Spach.).

Type locality: Newfield, N. J., on living white cedar [*Chamaecyparis thyoides*].

Distribution: Along the Atlantic coast from Massachusetts to Delaware, also in northern Florida and southern Alabama.

Illustrations: Farlow, Anniv. Mem. Boston Soc. Nat. Hist. *pl. 2, f. 13–17.*

Exsiccati: Rab.-Wint. Fungi Eur. *2920;* Thüm. Myc. Univ. *1936;* Roum. Fungi Sel. *4921;* Seym. & Earle, Econ. Fungi *246;* Ellis & Ev. Fungi Columb. *55;* Ellis, N. Am. Fungi *271.*

33. Gymnosporangium Betheli Kern, Bull. Torrey Club **34**: 459. 1907

Roestelia Betheli Kern, Bull. Torrey Club **34**: 461. 1907.

Aecia fruiticolous and hypophyllous, densely crowded, usually occupying only part of the surface of the fruits, in small groups on the leaf blades, cylindric, 0.2–0.3 mm. in diameter, 3–8 mm. high; peridium becoming finely lacerate above, often nearly to base, spreading; peridial cells long and narrow, curving somewhat when wet, broadly lanceolate in face view, 20–25×60–90μ, linear in side view, 13–20μ thick, outer wall 1–1.5μ thick, smooth, inner and side walls 4–6μ thick, rugose with closely set linear ridges and a few interspersed elongate papillae; aeciospores globoid, 18–24×23–30μ, wall chestnut brown, 2.5–3μ thick, finely verrucose.

Fig. 29. *G. Betheli.*

Telia caulicolous, appearing on irregular, elongated, gall-like knots usually breaking forth in succession along the branches and varying greatly in size and extent, unevenly disposed, wedge-shaped, 1–1.5 mm. broad by 1–3 mm. long at the base by 3–4 mm. high, chestnut-brown; teliospores 2-celled, ellipsoid, 17–25×37–53μ, rounded or somewhat narrowed above and below, slightly or not constricted at the septum, wall dark cinnamon-brown, 1–2μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Crataegus coloradensis* A. Nels., *C. chrysocarpa* Ashe, *C. erythropoda* Ashe (*C. cerronis* A. Nels.), *C. Douglasii* Lindl., *C. occidentalis* Britton, *C. rivularis* Nutt., *C. saligna* Greene.

For the telia: *Juniperus scopulorum* Sarg. (*Sabina scopulorum* Rydb.

Type locality: Boulder, Colorado, on *Sabina scopulorum*.

Distribution: Northeastern Washington and southeastern Oregon to Colorado.

Illustration: Bot. Gaz. **49**: *pl. 21, f. 5*.

Exsiccati: Barth. Fungi Columb. *2526, 2789, 2790*.

34. Gymnosporangium globosum Farlow, Anniv. Mem. Boston Soc. Nat. Hist. 34. 1880

Gymnosporangium fuscum globosum Farlow, Anniv. Mem. Boston Soc. Nat. Hist. 18. 1880.

Roestelia lacerata y, z, Thaxt. Proc. Am. Acad. **22**: 266. 1887.

Puccinia globosa Kuntze, Rev. Gen. Pl. **3**: 507. 1898.

Tremella globosa Arth. Proc. Ind. Acad. Sci. **1900**: 136. 1901.

Aecidium globosum Farlow, Bibl. Index **1**: 49. 1905.

Aecia chiefly hypophyllous, crowded in irregular or rarely annular groups 2–7 mm. across, cylindric, 1.5–3 mm. high by 0.1–0.2 mm. in diameter; peridium soon splitting in the upper part, becoming reticulate half way to base; peridial cells seen in both face and side views, broadly lanceolate in face view, 15–23×60–90μ, linear-rhomboid in side view, 13–19μ thick, outer wall about 1.5μ thick, smooth, inner and side walls 3–5μ thick, rather densely rugose with ridge-like papillae of varying length; aeciospores globoid or broadly ellipsoid, 15–19×18–25μ, wall light chestnut-brown, 1.5–2μ thick, finely verrucose.

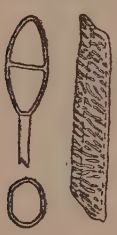


Fig. 30. *G. globosum.*

Telia caulicolous, appearing on irregular globoid gall-like excrescences 3–25 mm. in diameter, unevenly disposed, often separated by the scars of the sori of previous seasons, tongue- or wedge-shaped, 1.5–3 mm. broad by 2–5 mm. long at the base by 6–12 mm. high, chestnut-brown; teliospores 2-celled, ellipsoid, 16–21×37–48μ, somewhat narrowed above and below, slightly constricted at the septum, wall pale cinnamon-brown, 1–2μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Crataegus acutiloba* Sarg., *C. ancisa* Beadle, *C. anomala* Sarg., *C. apposita Bissellii* Egg., *C. arcuata* Ashe, *C. asperifolia* Sarg., *C. Biltmoreana* Beadle, *C. Boyntoni* Beadle, *C. Brainerdi* Sarg., *C. Buckleyi* Beadle, *C. Champlainensis* Sarg., *C. Chapmani* Ashe, *C. coccinea* L. (*C. modesta* Sarg.), *C. coccinoides* Ashe, *C. coccinoides dilitata* (Sarg.)

Eggl., *C. collina* Chapm., *C. colorata* Sarg., *C. conjuncta* Sarg., *C. conspicua* Sarg., *C. consueta* Sarg., *C. corusca* Sarg., *C. Crus-galli* L., *C. cyclophylla* Sarg., *C. decorata* Sarg., *C. delecta* Sarg., *C. delectabilis* Sarg., *C. delucida* Sarg., *C. demissa* Sarg., *C. dilitata* Sarg., *C. disjuncta* Sarg., *C. dispar* Beadle, *C. dispessa* Ashe (*C. pyriformis* Britton), *C. dissimilis* Sarg., *C. dissona* Sarg., *C. dumetosa* Sarg., *C. Eamesii* Sarg., *C. Edsoni* Sarg., *C. Egglestoni* Sarg., *C. Engelmani* Sarg., *C. festiva* Sarg., *C. Forbesae* Sarg., *C. fretalis* Sarg., *C. genialis* Sarg., *C. glaucophylla* Sarg., *C. harbisoni* Beadle, *C. Holmesianna* Ashe (*C. tenuifolia* Britton), *C. lasiantha* Sarg., *C. macilenta* Beadle, *C. macracantha* Lodd., *C. macracantha succulenta* (Schrad.) Eggl., *C. margaretta* Ashe, *C. McGeeae* Ashe, *C. membranacea* Sarg., *C. Mohri* Beadle, *C. mollis* (Torr. & Gray) Scheele, *C. Neo-Londonensis* Sarg., *C. Peckietta* Sarg., *C. pentandra* Sarg., *C. Pequotorum* Sarg., *C. pertomentosa* Ashe, *C. Phaenopyrum* (L. f.) Medic. (*C. cordata* Ait.), *C. pinguis* Sarg., *C. pisifera* Sarg., *C. polita Tatnalliana* (Sarg.) Egg., *C. praecox* Sarg., *C. Pringlei* Sarg., *C. pruinosa* (Wendl.) C. Koch., *C. pruinosa latisephala* (Ashe) Eggl. (*C. cognata* Sarg., *C. latisephala* Ashe), *C. punctata* Jacq., *C. Quinebangensis* Sarg., *C. Reverchoni* Sarg., *C. rhombifolia* Sarg., *C. roanensis* Ashe (*C. ascendens* Sarg.), *C. Robbinsiana* Sarg., *C. rotundifolia* Moench., *C. scabrida* Sarg., *C. Schweinitziana* Sarg., *C. submollis* Sarg., *C. tecta* Beadle, *C. tenella* Ashe, *C. tetrica* Beadle, *C. tomentosa* L., *C. Treleasii* Sarg., *Malus Malus* (L.) Britton, *Pyrus communis* L., *Sorbus americana* Marsh.

For the telia: *Juniperus barbadensis* L., *J. virginiana* L.

TYPE LOCALITY: Massachusetts, on *Juniperus virginiana.*

DISTRIBUTION: Maine west to southeastern South Dakota and south to northern Florida and Texas.

ILLUSTRATIONS: Farlow, Anniv. Mem. Boston Soc. Nat. Hist. *pl. 1, f. 7–11;* Bull. Iowa Exper. Sta. 84: *f. 3;* E. & P. Nat. Pflanzenfam. 1[1]**: *f. 34, A;* Hedwigia **34**: 3, *f. 6;* Bot. Gaz. **49**: *pl. 21, f. 4.*

EXSICCATI: Ellis & Ev. Fungi Columb. *758, 2028;* Ellis & Ev. N. Am. Fungi *2997, 2998;* Ellis, N. Am. Fungi *1478;* Thüm. Myc. Univ. *2139;* Sydow, Ured. *296, 1434, 2048;* Rab.-Wint.-Paz.

Fungi Eur. *4013;* Seym. & Earle, Econ. Fungi *230a, b, 231a, b, c, 232a, b, 233a, b;* Kellerm. Ohio Fungi *44;* Kellerm. & Sw. Kans. Fungi *2496;* Rav. Fungi Am. *481;* Shear, N. Y. Fungi *79, 123.*

35. **Gymnosporangium hyalinum** (Cooke)

Roestelia hyalina Cooke, Bull. Soc. Bot. France **24**: 314. 1877.
Aecidium hyalinum Farlow, Bibl. Index **1**: 55. 1905.

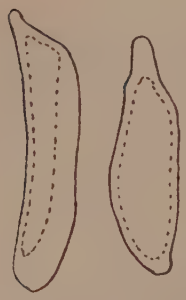


FIG. 31. *G. hyalinum.*

Aecia hypophyllous, gregarious, borne in small gall-like pyriform protuberances of a reddish brown color which are usually consolidated at their bases, cylindric, 2–5 mm. high by 0.2–0.3 mm. in diameter; peridium tardily rupturing with a few irregular slits along the sides, somewhat twisted but not spreading or recurved; peridial cells usually seen only in face view, lanceolate, 19–29×87–105μ, usually obtuse below and considerably narrowed above, walls smooth on all surfaces, inner and side walls 3–4μ thick, outer wall 12–16μ; aeciospores globoid, 19–26μ in diameter, wall light cinnamon-brown, 2–3μ thick, very moderately verrucose.

Telia unknown.

HOST PLANTS:

For the aecia: *Crataegus clara* Beadle, *C. dispar* Beadle, *C. egens* Beadle, *C. egregia* Beadle, *C. Michauxii* Pers., *C. munda* Beadle, *C. pexa* Beadle, *C. quasita* Beadle, *C. viridis* L., *C. visenda* Beadle.

TYPE LOCALITY: South Carolina on *Crataegus sp.*

DISTRIBUTION: Atlantic coast from North Carolina south to northern Florida.

ILLUSTRATION: Bot. Gaz. **49**: *pl. 22, f. 11.*

EXSICCATI: Rav. Fungi Am. 37.

36. GYMNOSPORANGIUM NELSONI Arth. Bull. Torrey Club **28**: 665. 1901.

Roestelia Nelsoni Arth. Bull. Torrey Club **28**: 665. 1901.
Aecidium Nelsoni Farl. Bibl. Index **1**: 68. 1905.
Gymnosporangium durum Kern, Bull. Torrey Club **34**: 460. 1907.

Aecia hypophyllous and fruiticolous, usually in small groups 1–2 mm. across, cylindric, 2–4 mm. high by 0.2–0.3 mm. in diam.;

peridium whitish, dehiscent at apex and also rupturing more or less along the sides; peridial cells seen in both face and side views, broadly lanceolate in face view, 18–35×75–115μ, linear-rhomboid in side view, 16–35μ thick, outer wall rather thin, 1.5–2μ, smooth, inner and side walls rather thick, 7–12μ, evenly and densely verruculose; aeciospores globoid, 19–26×21–29μ, wall chestnut-brown, 2–3μ thick, finely verrucose.

Fig. 32.*G. Nelsoni.*

Telia caulicolous, appearing on firm, woody, globose galls 0.5–5 cm. in diameter, unevenly disposed, densely aggregated or often separated by the scars of the sori of previous seasons, irregularly flattened, about 1–1.5 mm. broad by 1–5 mm. long at the base by 3–4 mm. high, often confluent, light chestnut-brown; teliospores 2-celled, narrowly ellipsoid, 18–26×50–65μ, narrowed at both ends, slightly constricted at the septum; wall pale cinnamon-brown, 1–1.5μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Cydonia vulgaris* (L.) Pers., *Amelanchier alnifolia* Nutt., *A. elliptica* A. Nels., *A. oreophila* A. Nels., *A. polycarpa* Greene, *A. pumila* Nutt., *Peraphyllum ramosissimum* Nutt., *Pyrus communis* L.

For the telia: *Juniperus monosperma* (Engelm.) Sarg. *J. scopulorum* Sarg., *J. utahensis* (Engelm.) Lemm.

Type locality: Laramie Hills, Wyoming, on *Juniperus scopulorum.*

Distribution: Alberta south to Colorado and Arizona.

Exsiccati: Ellis & Ev. Fungi Columb. *1676;* Garrett. Fungi Utah. *177.*

For explanation of the synonomy of this species see note under *G. juvenescens* (*No. 14*).

37. Gymnosporangium corniculans Kern, Mycologia **2**: 236. 1910

Aecia hypophyllous, crowded in irregular or sometimes annular groups 2–5 mm. across, on discolored hypertrophied spots, cylindric or horn-shaped, acutish at apex, 2–3.5 mm. high, 0.3–0.5 mm. in diameter; peridium not or only rarely rupturing at apex, very tardily dehiscent by longitudinal slits along the sides; peridial cells usually seen in face view, broadly lanceolate, 16–23×64–96μ, rhomboid in side view, 18–25μ thick, outer wall 1.5–2μ thick, smooth, inner and side walls rather thick, 5–7μ, moderately verrucose with oval or roundish papillae and a few delicate elongated

papillae interspersed; aeciospores globoid, 20–36×23–32μ, wall dark cinnamon-brown, 3–4μ thick; very finely verrucose, appearing nearly smooth.

Telia caulicolous, appearing on irregularly lobed gall-like excrescences, 2–15 mm. or more in diameter, unevenly disposed, often separated by the scars of the sori of previous seasons, conic or cylindric-acuminate, 1.5–2 mm. in diameter at base by 3–5 mm. high, dark chestnut-brown; teliospores 2-celled, ellipsoid, 18–21×35–50μ, usually rounded both above and below, slightly or not at all constricted at the septum, slightly enlarged near the septum in one or two places owing to the presence of hyaline thickenings over the germ-pores, wall light cinnamon-brown, thin, 1–1.5μ; hyaline thickenings about 1–1.5μ; pores 1–2 in each cell, near the septum.

FIG. 33. *G. corniculans.*

HOST PLANTS:

For the aecia: *Amelanchier canadensis* (L.) Medic., *A. erecta* Blanch., *A. intermedia* Spach., *A. oblongifolia* (Torr. & Gray) Roem., *A. sanguinea* (Pursh) Lindley.

For the telia: *Juniperus horizontalis* Moench (*J. prostrata* Pers.), *J. virginiana* L.

TYPE LOCALITY: Leland, Mich., on *Juniperus horizontalis.*

DISTRIBUTION: From Vermont and Massachusetts west to northern Illinois and eastern Iowa.

EXSICCATI: Seym. & Earle, Econ. Fungi *248a, b;* Ellis & Ev. Fungi Columb. *1827;* Ellis & Ev. N. Am. Fungi *2715.*

38. GYMNOSPORANGIUM FLORIFORME Thaxt.; Kern, Bull. Torrey Club **35**: 503. 1908

Roestelia flaviformis Atkinson; Underw. & Earle, Bull. Ala. Exp. Sta. 80: 218, hyponym. 1897.

Gymnosporangium flaviformis Earle, Contr. U. S. Herb. **6**: 186, hyponym. 1901.

Aecidium flaviformis Farlow, Bibl. Index **1**: 44, hyponym. 1905.

Aecia hypophyllous, rather widely separated in oblong-annular groups 2–6 mm. across, on thickened discolored spots, at first cylindric, 1–1.5 mm. high by 0.2–0.5 mm. in diameter; peridium rupturing extremely early and becoming finely fimbriate to base, strongly revolute; peridial cells usually seen only in side view, long and narrow, 10–14×65–85μ, becoming somewhat curved when

wet, outer wall 1.5–2μ thick, smooth, inner wall 4–5μ thick, rugose, side walls closely rugose with ridge-like markings extending nearly to outer side; aeciospores angular-ellipsoid, 18–23 × 23–29μ, wall chestnut-brown, 1.5–2.5μ thick; finely verrucose.

Fig. 34. *G. floriforme.*

Telia appearing on rather small, lobed, gall-like excrescences 3–10 mm. across, or occasionally on larger, globoid, or subreniform galls, usually numerous, rather evenly disposed, about 1–3 mm. apart, sometimes few in a ray-like arrangement at right angles to the short axis of the gall, conic or cylindric-acuminate, 1–1.5 mm. broad at base by 3–10 mm. long, chestnut-brown; teliospores 2-celled, narrowly ellipsoid, 15–19×39–50μ, rounded above and below, slightly or not constricted at the septum, wall pale cinnamon-brown, 1–1.5μ thick; pores 2 in each cell, near the septum.

Host plants:

For the aecia: *Crataegus spathulata* Michx.

For the telia: *Juniperus virginiana* L. (*Sabina virginiana* Antoine).

Type locality: Auburn, Lee County, Alabama, on *Sabina virginiana.*

Distribution: South Carolina and northern Florida westward to Arkansas and eastern Texas.

Illustration: Bot. Gaz. **49**: *pl. 21, f. 3.*

Exsiccati: Sydow, Ured. *1194.*

39. Gymnosporangium Juniperi-virginianae Schw. Schr. Nat. Ges. Leipzig **1**: 74. 1822

Gymnosporangium macropus Link, in Willd. Sp. Pl. **6**^{2}: 128. 1825.
Gymnosporangium virginianum Spreng. Syst. Veg. **4**: 562. 1827.
Podisoma Juniperi-virginianae Fries, Syst. Myc. **3**: 507. 1832.
Caeoma (*Aecidium*) *pyratum* Schw. Trans. Am. Phil. Soc. II. **4**: 294. 1832.
Podisoma macropus Schw. Trans. Am. Phil. Soc. II. **4**: 307. 1832.
Aecidium pyratum Schw. Trans. Am. Phil. Soc. II. **4**: 309. 1832.
Roestelia penicillata Farlow, Ann. Mem. Boston Soc. Nat. Hist. 30. 1880. Not *R. penicillata* Fries. 1849.
Roestelia pyrata Thaxt. Proc. Amer. Acad. **22**: 269. 1886.
Puccinia macropus Kuntze, Rev. Gen. Pl. **3**: 507. 1898.
Puccinia Juniperi-virginianae Arth. Proc. Ind. Acad. Sci. **1898**: 186. 1899.

Tremella Juniperi-virginianae Arth. Proc. Ind. Acad. Sci. **1900**: 135. 1901.

Aecidium Juniperi-virginianae Arth. Résult. Sci. Congr. Bot. Vienne 343. 1905.

Aecia chiefly hypophyllous, usually in annular groups, on thickened discolored spots, at first cylindric, 0.1–0.4 mm. in diameter; peridium splitting extremely early becoming fimbriate to the base, strongly revolute; peridial cells usually seen only in side view, long and narrow, 10–16 by 65–100μ, becoming much curved when wet, inner and side walls rather sparsely rugose with ridges extending half way across the side walls; aeciospores globoid or broadly ellipsoid, 16–24 by 21–31μ, wall light chestnut-brown, 2–3μ thick, finely verrucose.

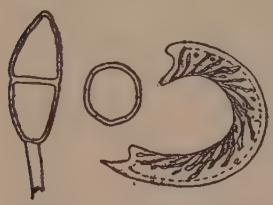


Fig. 35. *G. Juniperi-virginianae.*

Telia appearing on globoid or reniform galls 5–30 mm. or more in diameter, evenly disposed, cylindric or cylindric-acuminate, 1.5–3 mm. in diameter by 10–20 mm. long, golden-brown; teliospores 2-celled, rhombic-oval or narrowly ellipsoid, 15–21 by 42–65μ; slightly or not constricted at the septum, wall pale cinnamon-brown, thin, about 1μ; pedicel cylindric, 3–5μ in diameter; pores 2 in each cell near the septum.

Host plants:

For the aecia: *Malus angustifolia* (Ait.) Michx., *M. baccata* (L.) Desf., *M. coronaria* (L.) Mill., *M. ioensis* (Wood) Britton, *M. Malus* (L.) Britton.

For the telia: *Juniperus barbadensis* L., *J. virginiana* L.

Type locality: North Carolina, on *Juniperus virginiana.*

Distribution: Massachusetts and Ontario west to S. Dakota, south to Texas and Florida.

Illustrations: Farlow, Anniv. Mem. Boston Soc. Nat. Hist. *pl. 1, f. 1–6;* Ann. Bot. **1**: *pl. 13;* Bull. Iowa Exp. Station 84, *f. 1, 2, 5c;* Hedwigia **34**: 3, *f. 8;* Bot. Gaz. **49**: *pl. 21, f. 2;* E. & P. Nat. Pflanzenfam. **1**^{1**}: *f. 34B;* Ann. Rep. Neb. Exp. Station **22**: *f. 1–12.*

Exsiccati: Ellis & Ev. N. Am. Fungi *2713;* Ellis & Ev. Fungi Columb. *757, 1929, 2029, 2030;* Ellis, N. Am. Fungi *270, 1086a, b, 2713;* Kellerm. Ohio Fungi, *22;* Kellerm. & Sw. Kan. Fungi *19;* Carleton, Ured. Am. *39;* Rab.-Wint. Fungi Eur. *2921;* Rab.-Wint.-Paz. Fungi Eur. *4014;* Seym. & Earle, Econ. Fungi *227a, 228, 229, 229x, y;* Shear, N. Y. Fungi *317;* Sydow, Ured. *1195;* Thüm. Myc.

Univ. *148*, *732;* Rav. Fungi Am. *481;* Vesterg. Micr. Rar. Sel. *633;* Barth. Fungi Columb. *2626*, *3328;* Barth, N. Am. Ured. *107*.

40. Gymnosporangium bermudianum (Farlow) Earle; Seym. & Earle, Econ. Fungi *249*. 1893

Aecidium bermudianum Farlow, Bot. Gaz. **12**: 206. 1887.
Tremella bermudiana Arth. Proc. Ind. Acad. Sci. **1900**: 136. 1901.

Aecia appearing on globoid or subreniform galls of reddish brown luster (6–12 mm. in diameter), cylindric, 0.8–1.5 mm. high by 0.1–0.3 in diameter; peridium fragile, soon becoming lacerate, often to base, spreading but not recurved; peridial cells narrowly obovate in face view, 18–25 × 50–75,μ linear-rhomboid in side view, 15–18μ thick, outer wall thin, about 1.5μ, smooth, inner wall thicker, 3–5μ, moderately rugose with closely set ridge-like papillae of varying length; aeciospores globoid or polygonal, 16–19×19–39μ, wall dark chestnut-brown, 2–2.5μ thick, minutely verrucose.

Fig. 36. *G. bermudianum.*

Telia following the aecia on the same galls, few, irregularly disposed, pulvinate, low, roundish, 0.4–0.7 mm. across, dark cinnamon-brown; teliospores 2-celled, ellipsoid, 18–25×34–50μ, rounded or somewhat narrowed both above and below, slightly constricted at the septum, wall cinnamon-brown, thin, about 1μ; pores 2 in each cell, near the septum.

Host plants:

For the aecia and telia: *Juniperus barbadensis* L. (*Sabina barbadensis* Small), *J. bermudiana* L. (*S. bermudiana* Antoine), *J. lucayana* Britton, *J. virginiana* L. (*S. virginiana* Antoine).

Type locality: Bermuda, on *Juniperus virginiana*.

Distribution: Along the gulf coast from Mississippi to Florida, and in the Bermuda and Bahama Islands.

Illustration: Bot. Gaz. **49**: *pl. 21, f. 1*.

Exsiccati: Seym. & Earle, Econ. Fungi *249*, *250*.

Excluded or Doubtful Species

Gymnosporangium asiaticum Miyabe, Bot. Mag. **17**[2]: 34, hyponym. 1903. On *Pyrus sinensis* Lindl. and *Cydonia vulgaris* (L.) Pers. Doubtful, the form on *P. sinensis* may be *G. japonicum*.

Gymnosporangium Sabinum Fries, Syst. Myc. **3**: 507. 1832. Not a *Gymnosporangium*.

Hamaspora longissima (Thüm.) Körn. Hedw. **16**: 23. 1877. A *Phragmidium*.

Podisoma foliicola Berk.; Smith, Eng. Flora 5^2: 362. 1836. Not a rust but one of the Fungi Imperfecti referred to the genus *Hendersonia* by Fuckel.

Roestelia guaranitica De Toni, in Sacc. Syll. Fung. **7**: 833. (*Ceratitium guaraniticum* Speg. Anal. Soc. Ci. Argent. **17**: 126. 1884.) On *Salvia* and may belong to a *Puccinia*.

Roestelia interveniens Peck, Bull. Torrey Club **10**: 74. 1883. Doubtful, may belong to a *Puccinia*.

Roestelia phaeospora De Toni, in Sacc. Syll. Fung. **7**: 834. (*Ceratitium phaeosporum* Ces. Mycet. Born. 26. 1879.) On an unknown plant; may belong here but it is impossible to say from such incomplete information.

Roestelia polita Berk. Linn. Journ. **13**: 174. 1872. The aecial stage of an autoecious *Uromyces*.

Bibliography

Arthur, J. C.

1901.—Generic Nomenclature of Cedar Apples. Proc. Ind. Acad. Sci. **1900**: 131–136.

1906.[1]—Eine auf die Struktur und Entwicklungsgeschichte begründete Klassifikation der Uredineen. Résult. Sci. Congr. Bot. Vienne 331–348.

1906.[2]—Reasons for Desiring a Better Classification of the Uredinales. Jour. Myc. **12**: 149–154.

1907.—Cultures of Uredineae in 1906. Jour. Myc. **13**: 189–205.

1908.[1]—Cultures of Uredineae in 1907. Jour. Myc. **14**: 7–26.

1908.[2]—A Search for Rusts in Colorado. Plant World **11**: 69–77.

1909.—Cultures of Uredineae in 1908. Mycologia **1**: 225–256.

1910.[1]—Cultures of Uredineae in 1909. Mycologia **2**: 213–240.

1910.[2]—Right and Wrong Conceptions of Plant Rusts. Proc. Ind. Acad. Sci. **1909**: 383–390.

Barclay, A.

1890.—On the Life-History of a Himalayan *Gymnosporangium* (*G. Cunninghamianum*, nov. sp.). Sci. Mem. Med. Off. India **5**: 71–78, *pls. I–III*.

Bethel, E.

1911.—Notes on some species of *Gymnosporangium* in Colorado. Mycologia **3**: 156–160.

Blackman, V. H.

1904.—On the Fertilization, Alternation of Generations, and General Cytology of the Uredineae. Ann. Bot. **18**: 323–373.

Christman, A. H.

1905.—Sexual Reproduction in Rusts. Bot. Gaz. **39**: 267–274.

1907.—Alternation of Generations, and the Morphology of the Spore-forms in Rusts. Bot. Gaz. **44**: 81–101.

Cook, M. C.
1887.—Notes on *Podisoma*. Jour. Quek. Microscop. Club **2**: 255–268.
Dietel, P.
1889.—Ueber das Vorkommen von Zweierlei Teleutosporen bei der Gattung *Gymnosporangium*. Hedwigia **28**: 99–103.
1895.—Ueber die Unterscheidung von *Gymnosporangium juniperinum* und *G. tremelloides*. Forst. Nat. Zeits. **4**: 346–349.
1899.—Waren die Rostpilze in früheren Zeiten plurivor? Bot. Centr. **79**: 81–85, 113–117.
Ellis, J. B.
1883.—Notes on *Gymnosporangium* and *Roestelia*. Amer. Nat. **17**: 1281–82.
Farlow, W. G.
1880.—The *Gymnosporangia* or Cedar-Apples of the United States. Anniv. Mem. Boston Soc. Nat. Hist.
1885.—Notes on some species of *Gymnosporangium* and *Chrysomyxa* of the United States. Proc. Amer. Acad. **20**: 311–323.
1887.—The Development of the *Gymnosporangia* of the United States. Bot. Gaz. **12**: 205–207.
1887.—*Aecidium* on *Juniperus virginiana*. Bot. Gaz. **12**: 205–207.
Fentzling, K.
1892.—Morphologische und anatomische Untersuchungen der Veränderungen, welche bei einigen Pflanzen durch Rostpilze hervorgerufen werden. (Inaugural-Dissertation.) Freiburg.
Fischer, Ed.
1895.—Die Zugehorigkeit des *Aecidium penicillatum*. Hedwigia **34**: 1–6.
1904.—Die Uredineen der Schweiz. Beitr. z. Kryptogamenflora d. Schweiz **2²**.
1907.—Biologie du Genre *Gymnosporangium* des Urédinées. Archiv. d. sc. physiques et naturelles. 4 Période. **24**.
1909.—Studien zur Biologie von *Gymnosporangium juniperinum*. Zeits. f. Bot. **1**: 683–714.
1910.—Studien zur Biologie von *Gymnosporangium juniperinum*—II. Zeits. f. Bot. **2**: 753–764.
Heald, F. D.
1907.—*Gymnosporangium macropus*. Science, N. S. **26**: 219–220.
1909.—The Life-history of the Cedar Rust Fungus. Ann. Rep. Neb. Agric. Experiment Station **22**: 105–113, *pl. 1–13*.
Hein, W. H.
1908.—Cedar Rust (*Gymnosporangium macropus*). Insect Pest and Pl. Dis. Bur. of Neb. cir. no. 1, Div. of Bot.
Kern, Frank D.
1907.—New western species of *Gymnosporangium* and *Roestelia*. Bull. Torrey Bot. Club **34**: 459–463.
1908.[1]—The Existence of *Roestelia penicillata* and its telial phase in North America. Science **27**: 930–931.
1908.[2]—Studies in the genus *Gymnosporangium*. Bull. Torrey Bot. Club **35**: 499–511.
1909.—A notable species of *Gymnosporangium* from Colorado. Mycologia **1**: 208–210.

1910.[1]—Prediction of Relationships among some Parasitic Fungi. Science **31**: 830–833.

1910.[2]—The Morphology of the Peridial Cells in the *Roesteliae*. Bot. Gaz. **49**: 445–452.

KIENITZ-GERLOF, F.

1888.—Die Gonidien von *Gymnosporangium clavariaeforme*. Bot. Zeit. **46**: 389–393.

KÖRNICKE, F.

1877.—Mycologische Beiträge. Hedwigia **16**: 22–28.

1892.—Bemerkungen über *Gymnosparangium confusum* Plowr. und G. *Sabinae* (Dicks.). Zeits. f. Pflanzenkr. **2**: 94–95.

KLEBAHN, H.

1904.—Die Wirtswechselnden Rostpilze.

1905.—Kulterversuche mit Rostpilzen. 12 Bericht (1903 u. 1904). Zeits. f. Pflanzenkr **15**: 65–108 (pp. 79–80).

1907.—Kulterzersuch mit Rostpilzen. 13 Bericht (1905 u. 1906). Zeits. f. Pflanzenkr. **17**: 129–157 (pp. 137–138).

LLOYD, F. E., AND RIDGWAY, C. S.

1911.—Cedar-apples and Apples. Bull. of Ala. Agric. Dept. No. 39.

LIRO, J. I.

1906.—Kulterversuche mit finnischen Rostpilzen, I. Acta. Soc. Pro. fauna et flora Fennica **29**[6]: 1906.

1908.—Uredineae fennicae. (Finlands Rostsvampor).

MIYABE, K.

1903.—On *Gymnosporangium* (Articles of Sapporo Botanical Society—in Japanese). Bot. Mag. Tokyo **17**[2]: 34–35.

OERSTED, A. S.

1865.—Vorläufige Berichterstattung über einige Beobachtungen, welche beweisen, dass *Podisona Sabinae*, welches auf den Zweigen von *Juniperus Sabina* wächst, und *Roestelia concellata*, welche die Blätter der Birbäume angreift, wechselnde Erzeugnisse derselben Pilzart sind. Bot. Zeit. **23**: 291–293.

1866.[1]—Indpodningsforsög, hvorved det bevises, at der finder et Generationsskifte sted mellem den paa Enens Grene snyltende Baevrerust (*Podisoma juniperinum*) og den paa Rönnens Blade voxende Hornrust (*Roestelia cornuta*). Overs. Danske Vid. Selsk. Forh. **1866**: 185–196, *pl. 3–4*.

1866.[2]—Nouvelles observations sur un champignon parasite dont les générations alternantes habitent sur deux plantes hospitalières différentes. Bull. d. l'acad. royale d. sciences de Copenhague.

1867.—Ueber *Roestelia lacerata* (Sow), nebst Bemerkungen über die andere Arten der Gattung *Roestelia*. Bot. Zeit. **25**: 222–223.

OLIVE, E. W.

1908.[1]—Sexual Cell Fusions and Vegetative Nuclear Divisions in the Rusts. Ann. Bot. **22**: 331–360.

1908.[2]—The Relationships of the Aecidium-cup type of Rusts. Abstract in Science **27**: 214–215.

PAMMEL, L. H.

1905.—Cedar Apple Fungi and Apple Rust in Iowa. Bull. Iowa Experiment Station 84.

1906.—Some Phytopathological Problems. Proc. Soc. Prom. Agric. Sci. for 1906.

Peglion, D. V.

1893.—Reserche anatomische sopra i tumori delle foglie e rami di Pero causati dal parassitismo della *Roestelia cancellata*. Riv. Patol. Veg. **2**: 23–37.

Plowright, C. B.

1889.—British Uredineae and Ustilagineae.

1888.—Experimental Observations on certain British Heteroecious Uredines. Journ. Linn. Soc. **24**: 88–101.

Richards, H. M.

1889.—The Uredo-Stage of *Gymnosporangium*. Bot. Gaz. **14**: 211–216.

1896.—On some Points in the Development of *Aecidia*. Proc. Amer. Acad. **31**: 255–270.

Sanford, Elmer

1888.—Microscopical Anatomy of the Common Cedar-Apple (*Gymnosporangium macropus*). Ann. Bot. **1**: 263–268.

Sappin-Trouffy, P.

1896.—Recherches histologiques sur la famille des Uredinées. Le Botaniste **5**: 59–244.

Shiraí, M.

1900.—Uber den genetischen Zusammenhang zwischen *Roestelia koreaensis* P. Henn. und *Gymnosporangium japonicum* Syd. Zeits. f. Pflanzenkr. **10**: 1–5, *pl. 1–2*.

Stevens, F. L., and Hall, J. G.

1910.—Diseases of Economic Plants.

Stewart, F. C.

1910.—Notes on New York Plant Diseases, I. Bull, N. Y. Agric. Exper. Sta. 328.

Stone, G. E.

1901.—Quince Rust. Mass. State Board of Agric. Nature Leaflet No. 11.

Stone, R. E.

1908.—Cedar Apples and Apple Leaf-Rust. Cir. Ala. Experiment Station No. 2.

1909.—Species of *Gymnosporangium* in Southern Alabama. Torreya **9**: 114–117.

Thaxter, R.

1887.—On certain Cultures of *Gymnosporangium*, with Notes on their *Roesteliae*. Proc. Amer. Acad. **22**: 259–269.

1889.—Notes on Cultures of *Gymnosporangium* made in 1887 and 1888. Bot. Gaz. **14**: 163–172.

1891.—The Connecticut Species of *Gymnosporangium* (Cedar Apples). Bull. Conn. Agric. Experiment Station No. 107.

Tubeuf, K. von

1895.—Pflanzenkrankheiten durch Kryptogame Parasiten verursacht 396–416.

1906.—Uberwinterung des Birnenrostes auf dem Birnbaum. Nat. Zeits. Land- u. Forstw. **4**: 150–152.

1907.—Perennieren des Acidienmycels vom Birnenrostpilz. Nat. Zeits. Land- u. Forstw. **5**: 217–219.

Tubeuf, K. von, and Smith, W. G.

1897.—Diseases of Plants induced by Cryptogamic Parasites 383–403.

Underwood, L. M., and Earle, F. S.

1896.—The Distribution of the Species of *Gymnosporangium* in the South. Bot. Gaz. **22**: 255–258.

Wakker, J. H.
1892.—Untersuchungen über den Einfluss parasitischer Pilze auf ihrer Nahrpflanzen—*Roestelia lacerata* auf *Crataegus*. Jahrb. f. wissenshaftliche Bot. **24**: 499–544 (pp. 511–513).
Whetzel, H. H.
1903.—Notes on Apple Rusts. Proc. Ind. Acad. Sci. **1902**: 255–261.
Woernle, P.
1894.—Anatomische Untersuchung der durch *Gymnosporangium*-Arten hervorgerufenen Missbildungen. Forst. Nat. Zeits. **3**: 68, 129.
Yamada, G., and Miyake, I.
1908.—Eine neue *Gymnosporangium*art. Bot. Mag. Tokyo **22**[1]: 21–28.

Explanation of Illustrations

Text-Figures

Fig. 1. Full explanation included with it.

Figs. 2–36. The names are given under each figure. The drawings were outlined with the aid of a camera lucida at a uniform scale and were reduced equally in reproduction, representing approximately a magnification of 350 diameters. In all drawings of peridial cells the end which is uppermost is the upper end of the cell, or the end which is toward the apex of the peridium. In all peridial cells except those in figures 3 and 31 the inner wall is the thicker. In figures 8, 31, and 36 face views of peridial cells are given and in figure 5 is a cross section.

Plate 151

(Frontispiece)—*Gymnosporangium Juniperi-virginianae*. The common "Cedar-apple."

Plate 152

Fig. 37. (19) *G. cornutum* on *Sorbus aucuparia;* typical groups of epiphyllous pycnia, (K) pycniospore. After Oersted (1866[1] *pl. 4*).

Fig. 38. *G. Sorbi* on *Sorbus occidentalis;* aecia short, cupulate.

Fig. 39. *G. cornutum* on *Sorbus americana;* elongated aecia, the peridium retaining its tubular or cornute form after dehiscence.

Fig. 40. *G. corniculans* on *Amelanchier erecta;* elongated aecia, the peridium retaining its tubular or cornute form after dehiscence.

Plate 153

Fig. 41. *G. germinale* on *Cydonia vulgaris;* elongated aecia, the peridium soon becoming deeply lacerate, erect or spreading. After Stewart.

Fig. 42. *G. Juniperi-virginianae* on *Malus Malus* (fruit); elongated aecia, the peridium soon becoming fimbriate and strongly revolute.

Fig. 43. *G. bermudianum* on *Juniperus barbadensis;* autoecious, aecia elongated, appearing on galls like the telia.

Plate 154

Fig. 44. *G. Blasdaleanum* on *Heyderia decurrens;* telia foliicolous, not causing hypertrophy, pulvinate.

Fig. 45. *G. inconspicuum* on *Juniperus utahensis;* telia between scale-like leaves with little or no hypertrophy.

Fig. 46. *G. Davisii* on *Juniperus sibirica;* telia epiphyllous, hemispheric.

Fig. 47. *G. cornutum* on *J. communis;* showing some foliicolous telia, they are usually caulicolous, see *Pl. 160, f. 62, 63*. After Oersted (1866[1] *pl. 3. f. 1*).

Fig. 37. G. CORNUTUM (After Oersted)

Fig. 38. G. SORBI (Enlarged)

Fig. 39. G. CORNUTUM

Fig. 40. G. CORNICULANS

FIG. 41. G. GERMINALE (AFTER STEWART)

FIG. 42. G. JUNIPERI-VIRGINIANAE

FIG. 43. G. BERMUDIANUM (AECIA)

FIG. 44. G. BLASDALEANUM

FIG. 45. G. INCONSPICUUM

FIG. 46. G. DAVISII

FIG. 47. G. CORNUTUM (AFTER OERSTED)

Fig. 48. G. BOTRYAPITES

Fig. 49. G. JUNIPERINUM

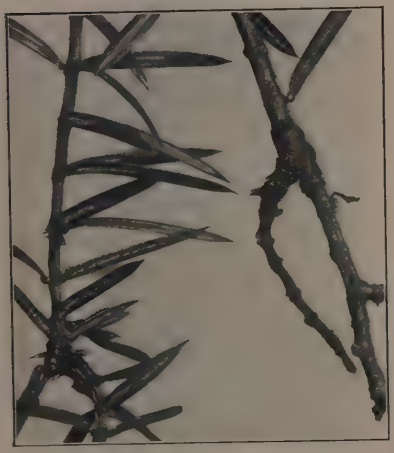


Fig. 50. G. GERMINALE

Fig. 51. G. GERMINALE

Fig. 52. G. KERNIANUM (After Bethel)

Fig. 53. G. JUVENESCENS (After Bethel)

Fig. 54. G. NIDUS-AVIS

Fig. 55. G. NIDUS-AVIS

Fig. 56. G. EXTERUM

Fig. 57. G. CLAVARIAEFORME
(Before Expansion)

Fig. 58. G. CLAVARIAEFORME
(After Expansion)

Fig. 59. G. BETHELI Fig. 60. G. EFFUSUM Fig. 61. G. GRACILENS

Fig. 62. G. CORNUTUM
(After Oersted)

Fig. 63. G. CORNUTUM

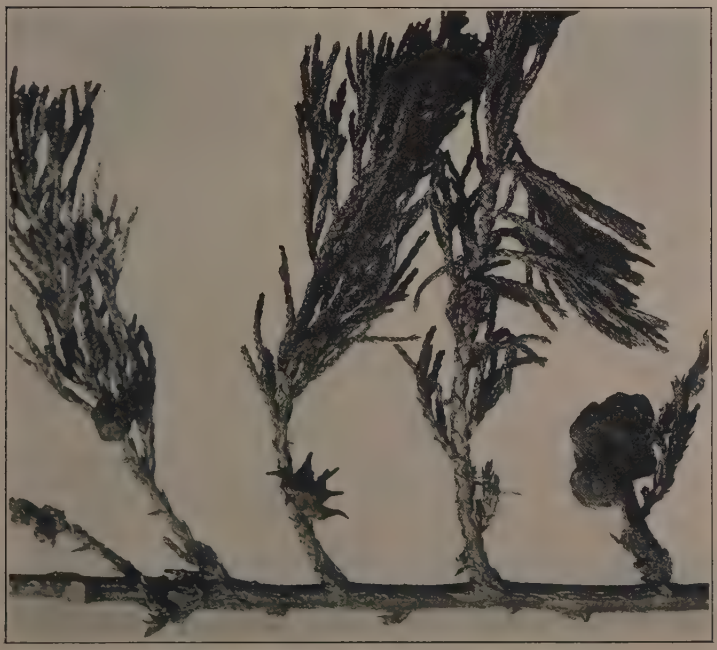


Fig. 64. G. CORNICULANS

Fig. 65. G. JUNIPERI-VIRGINIANAE

Fig. 66. G. JUNIPERI-VIRGINIANAE

Fig. 67. G. GLOBOSUM

Fig. 68. G. NELSONI

PLATE 155

Fig. 48. *G. Botryapites* on *Chamaecyparis thyoides;* telia hemispheric on a fusiform enlargement.

Fig. 49. *G. juniperinum* on *J. sibirica;* telia applanate on fusiform swelling.

Fig. 50. *G. germinale* on *J. sibirica* (§ *Oxycedrus*); telia small, caulicolous, not causing much hypertrophy.

Fig. 51. *G. germinale* on *J. virginiana* (§ *Sabina*); telia small, caulicolous, not causing much hypertrophy.

PLATE 156

Fig. 52. *G. Kernianum* on *Juniperus utahensis;* two dense witches' brooms, the leaves not showing a reversion to the juvenile form. After Bethel.

Fig. 53. *G. juvenescens* on *Juniperus scopulorum;* a witches' broom, the leaves showing the tendency, characteristic of this species, to revert to the juvenile form. After Bethel.

PLATE 157

Fig. 54. *G. Nidus-avis* on *J. virginiana;* showing way in which the branch system is often distorted (from photograph by Shear).

Fig. 55. *G. Nidus-avis* on *J. virginiana;* showing character of telia on the larger branches.

Fig. 56. *G. exterum* on *J. virginiana;* telia applanate and anastomosing over surface of a fusiform swelling.

PLATE 158

Fig. 57. *G. clavariaeforme* on *J. sibirica;* telia mature but dry.

Fig. 58. *G. clavariaeforme* on *J. sibirica;* the same specimen a short time after spraying it with water.

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Fig. 59. *G. Betheli* on *J. scopulorum;* telia on irregular galls which break forth in succession, giving an elongated area of hypertrophy.

Fig. 60. *G. effusum* on *J. virginiana;* telia wedge-shaped and lacunose on a fusiform enlargement.

Fig. 61. *G. gracilens* on *J. utahensis;* telia cristiform, on a slight swelling.

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Fig. 62. *G. cornutum* on *J. communis;* from a European specimen. After Oersted (1866[1], *pl. 3. f. 2*).

Fig. 63. *G. cornutum* on *J. sibirica;* from an American specimen.

Fig. 64. *G. corniculans* on *J. horizontalis;* telia conic, on globoid galls originating in the twigs.

PLATE 161

Fig. 65. G. *Juniperi-virginianae* on *J. virginiana;* very young galls showing origin in a leaf.

Fig. 66. *G. Juniperi-virginianae* on *J. virginiana;* an older gall showing reniform shape but still showing no indication of telia. See *Pl. 151* (frontispiece) for a mature specimen with the cylindric-acuminate telia.

Fig. 67. *G. globosum* on *J. virginiana;* telia wedge-shaped, separated by the scars of the sori of previous seasons.

Fig. 68. *G. Nelsoni* on *J. utahensis;* telia thin, irregularly flattened, gall globoid and very hard and woody.

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